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The Unionid Mollusks of the Upper Kansas Basin of Northwestern Kansas and Southwestern Nebraska

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THE UNIONID MOLLUSKS OF THE UPPER KANSAS BASIN OF NORTHWESTERN KANSAS AND SOUTHWESTERN NEBRASKA

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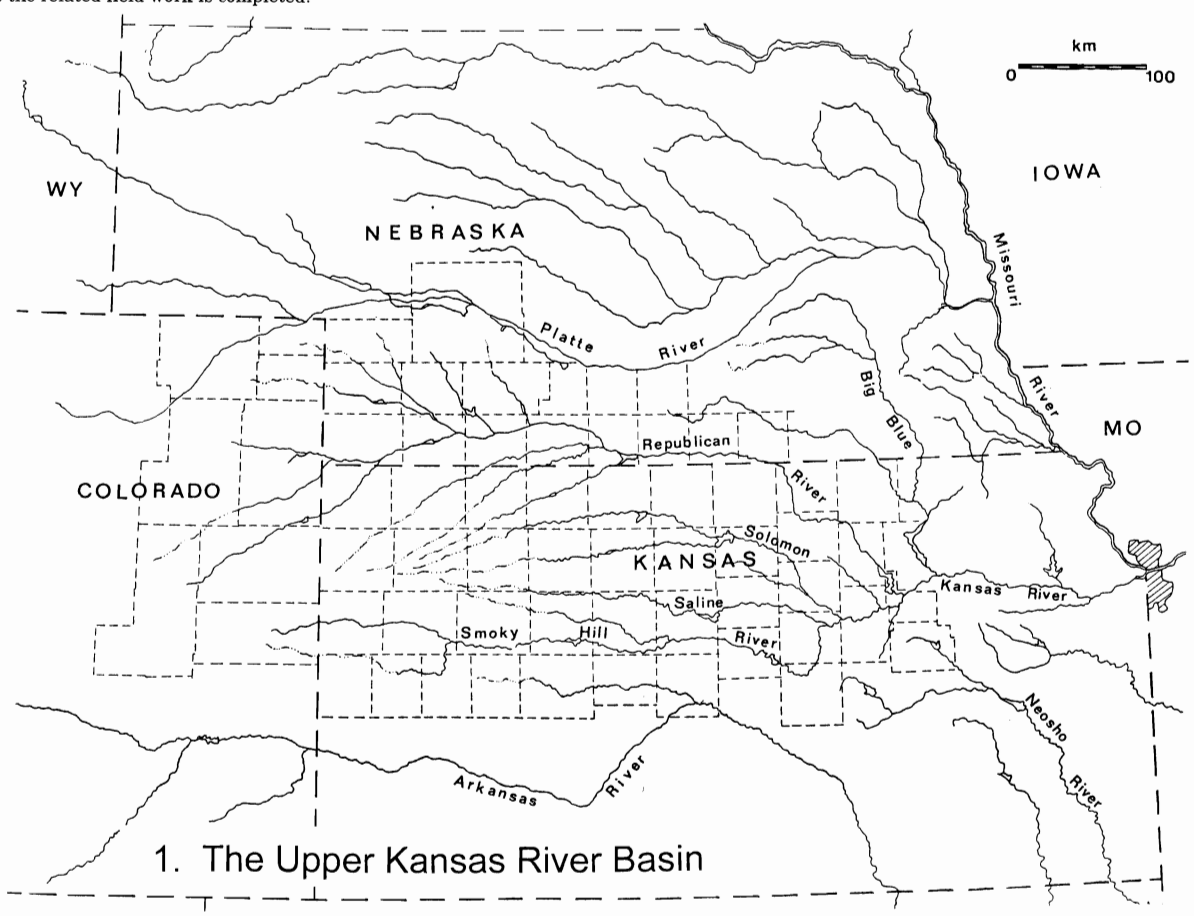
ABSTRACT

A qualitative survey of the Upper Kansas Basin resulted in the documentation of a unionid fauna consisting of twenty-one native taxa, as well as the introduced bivalve *Corbicula fluminea*. Biological diversity was greatest in the extreme eastern portion of the basin with the highest concentrations occurring in the habitat-rich eastern-most creeks. Shifting sand substrates and declining or unstable flows, coupled with intensive grazing of livestock, increasingly limit unionid distributions on an east to west continuum.

Note: This report is the fourth in a series on the unionid fauna of Nebraska and the central plains and the first report on the unionid fauna of the Kansas River Basin. A paper on the bivalve fauna of the Big and Little Blue River basins is in preparation, and a report on the lower portion of the Kansas Basin will be prepared as the related field work is completed.

† † †

Extending eastward from the plains of Colorado into southwestern Nebraska and northwestern Kansas, the Upper Kansas Basin, as herein defined, encompasses an area of 116,195 km^2 (Map 1). It may be divided into two parts corresponding to its two primary tributaries: the Republican River Basin with an area of 64,522 km^2, and the Smoky Hill River system covering a drainage of 51,673 km^2. The drainage basin of the former lies primarily within Kansas and Nebraska, while that of the latter is principally within Kansas. The confluence of these two rivers near Junction City, Kansas, forms the Kansas River.



1. The Upper Kansas River Basin

Table 1. Unionid mollusks collected from the Smoky Hill River Basin (excluding the Solomon and Saline basins) by collection site. L = live; F = fresh dead; R = recent shell; D = dry shell; WD = weathered shell; S = subfossil or chalky shell. An asterisk (*) indicates live specimen noted but not retained. Arrangement of taxa follows Stansbery and Borror (1983).

	Smoky Hill River mainstem							
Collection sites:	1	8	11	15	16	17	18	19
Year collected:	1983	1983	1983	1983	1983	1983	1983	1983
Taxa collected [map number]								
1. *Utterbackia imbecillis* (Say, 1829) [5]	–	–	–	–	–	–	–	–
2. *Pyganodon grandis grandis* (Say, 1829) [6]	–	–	–	–	S	–	–	–
3. *Anodontoides ferussacianus* (Lea, 1834) [7]	–	–	–	–	–	S	–	S
4. *Strophitus undulatus undulatus* (Say, 1817) [8]	–	–	–	–	S	S	–	–
5. *Lasmigona complanata* (Barnes, 1823) [9]	R	S	–	–	–	–	–	–
6. *Tritogonia verrucosa* (Rafinesque, 1820) [10]	S	WD	–	–	–	–	–	–
7. *Quadrula quadrula* (Rafinesque, 1820) [11]	L	–	–	–	S	S	–	–
8. *Quadrula pustulosa pustulosa* (Lea, 1831) [12]	S	WD	S	S	S	WD	L	S
9. *Amblema plicata plicata* (Say, 1817) [13]	S	–	–	–	–	–	–	–
10. *Fusconaia flava* (Rafinesque, 1820) [14]	–	–	–	–	–	–	–	–
11. *Uniomerus tetralasmus* (Say, 1830) [15]	–	–	–	–	–	–	–	–
12. *Obovaria olivaria* (Rafinesque, 1820) [16]	S	WD	–	S	–	–	–	–
13. *Truncilla donaciformis* (Lea, 1827) [13]	–	S	S	–	–	–	–	–
14. *Leptodea fragilis* (Rafinesque, 1820) [17]	R	L	D	F	D	L	R	D
15. *Potamilus ohiensis* (Rafinesque, 1820) [18]	L*	L	R	L	D	D	R	D
16. *Toxolasma parvus* (Barnes, 1823) [19]	–	–	–	–	–	–	–	–
17. *Ligumia subrostrata* (Say, 1831) [20]	–	–	–	–	–	–	–	–
18. *Lampsilis teres* f. *teres* (Rafinesque, 1820) [21]	S	S	S	–	S	–	–	–
19. *Lampsilis teres* f. *anodontoides* (Lea, 1831) [21]	–	–	–	–	–	–	–	–
20. *Lampsilis radiata luteola* (Lamarck, 1819) [22]	–	–	–	–	–	–	–	–
21. *Lampsilis ventricosa* (Barnes, 1823) [23]	–	S	–	–	–	–	–	–
22. *Corbicula fluminea* (Muller, 1774) [24]	–	–	–	–	–	–	–	–
23. Unidentifiable unionid taxa	–	–	–	–	–	–	–	–
Total taxa collected:	**9**	**9**	**5**	**4**	**7**	**6**	**3**	**4**

The region has been the center of an extensive series of water development projects for flood control and irrigation over the past 50 years. Following a disastrous flood on May 30, 1935, a series of six dams was constructed by the Federal government in the Upper Republican Basin in an effort to prevent future floods and to provide irrigation and recreation for the region (Hoffman 1983a). Dams were also constructed in Kansas on the Smoky Hill River and its two primary tributaries, the Saline and Solomon rivers, as well as on the Republican River near Milford and White Rock Creek in the Kansas portion of the Republican Basin.

More recently, the development of center-pivot irrigation technology has stimulated the drilling of large numbers of wells throughout the entire region. The Upper Kansas Basin currently is characterized by declining water tables and diminished stream flows. Ratzlaff (1994) has demonstrated that these declines are not due to natural climatological causes but instead reflect changes in the agricultural practices of the region.

The unionid fauna of the Upper Kansas Basin has been largely unstudied, and published reports have been limited to scattered records often reflecting only a handful of collecting sites more fully discussed later. The study area occupies a geographical position between the relatively rich fauna of the lower Kansas Basin (Leonard 1949) and the limited or absent fauna of the plains of eastern Colorado. As such it forms a natural transition zone for unionids. The absence of extensive previous work in the area, coupled with the significant habitat losses in the region resulting from the degradation of riparian habitats, provided the stimulus for a thorough survey of the area.

Table 1. Continued.

	Smoky Hill River mainstem, continued												
Sites:	20	21	22	23	24	25	26	27	28	30	32	39	40
Year:	1983	1983	1983	1986	1986	1983	1986	1983	1983	1983	1983	1983	1983
1.	–	–	–	–	–	–	–	–	–	–	–	–	–
2	–	–	D	D	S	–	–	S	–	–	R	–	–
3.	–	–	–	–	WD	D	WD	D	D	S	L*	R	–
4.	S	–	–	–	–	–	–	–	S	–	–	–	–
5.	–	–	–	–	–	–	–	–	S	–	–	–	–
6.	–	–	–	–	–	–	–	–	–	–	–	–	–
7.	–	L	D	L	L	–	–	S	–	WD	R	L*	–
8.	S	–	–	–	–	–	–	–	–	–	–	–	–
9	–	–	–	–	–	–	–	–	–	–	–	–	–
10.	–	–	–	–	–	–	–	–	–	–	–	–	–
11.	–	–	–	S	–	D	WD	S	D	WD	–	–	–
12.	–	–	–	–	–	–	–	–	–	–	–	–	–
13.	–	–	–	–	–	–	–	–	–	–	–	–	–
14.	R	–	–	–	–	–	–	–	–	–	–	–	–
15.	D	D	D	L	L	D	R	D	D	L	L*	D	–
16.	–	–	–	–	–	–	WD	–	–	–	–	–	–
17.	–	–	–	–	–	–	WD	S	S	–	–	–	–
18.	–	–	–	–	–	–	–	–	–	–	–	–	–
19.	–	–	–	–	–	–	–	–	–	–	–	–	–
20.	–	–	–	–	–	–	–	–	–	–	–	–	–
21.	–	–	–	–	–	–	–	–	–	–	–	–	–
22.	–	–	–	–	–	–	–	–	–	–	–	–	–
23.	–	–	–	–	–	–	–	S	S	–	–	–	S
Tot. taxa:	**4**	**2**	**3**	**4**	**4**	**3**	**5**	**7**	**7**	**4**	**4**	**3**	**1**

GOALS AND METHODS

The goals of this study were to document the current and, to the extent possible, past distributions of bivalve mollusks in the Upper Kansas Basin. A secondary goal was to gain an understanding of the natural and man-made parameters impacting unionids in the region, and to develop a model for the distributions observed.

The fieldwork for this project spanned a period of 26 years, but most of the collecting activity occurred in a relatively small number of collecting seasons. The Smoky Hill system was surveyed almost entirely in 1983, and the Republican Basin was researched primarily during the years 1972, 1981, 1990, and 1997. All collecting was done by the author.

Collection sites were selected at intervals of 15 to 20 km along all of the area's rivers and larger creeks. In some instances this interval was compressed when unusually productive or interesting areas were encountered. This occurred in the Smoky Hill Basin along Lyon Creek, and in the Republican Basin on Buffalo, Muddy, and Medicine Creeks. Collection-site intervals were also compressed along the shores of area reservoirs. Collecting intervals were further influenced by access conditions.

Though most efforts were directed at sampling the rivers of the region, area creeks and reservoirs were also extensively collected. In total, 42 creeks, 4 lakes, 2 canal systems, and 13 reservoirs were sampled in this survey of the Upper Kansas Basin in addition to the collection sites along all of the region's rivers.

Unionids were collected by hand or with the use of a garden rake primarily under low water conditions. This was particularly true of the Smoky Hill system which was collected during the height of the 1983

Table 1. Continued.

	Smoky Hill River mainstem, cont.					Smoky Hill River tributaries							
						Lyon Creek					Carry Creek	Chapman Creek	
Sites:	41	42	43	44	45	2	3	4	6	7	5	9	10
Year:	1983	1983	1983	1983	1983	1983	1983	1983	1983	1983	1983	1988	1988
1.	–	–	–	–	–	–	–	–	–	–	–	–	–
2.	–	–	–	–	WD	–	L*	R	R	L*	–	D	L
3.	R	F	R	R	–	–	–	–	–	–	–	–	–
4.	–	–	–	–	–	–	R	R	R	F	–	–	–
5.	–	–	–	–	–	WD	R	L*	R	F	–	–	L
6.	–	–	–	–	–	–	–	–	–	–	–	–	–
7.	R	F	R	R	D	WD	R	D	R	F	R	L	L
8.	–	–	–	–	–	–	–	S	–	–	–	–	–
9.	–	–	–	–	–	S	S	S	S	WD	–	S	–
10.	–	–	–	–	–	S	S	R	R	S	–	S	–
11.	–	–	–	–	–	–	–	–	–	–	–	–	–
12.	–	–	–	–	–	–	–	–	–	–	–	–	–
13.	–	–	–	–	–	–	–	–	–	–	–	–	–
14.	–	–	–	–	–	R	R	R	R	L*	–	D	–
15.	–	F	–	–	–	R	–	D	R	L*	–	–	–
16.	–	–	–	–	–	–	–	–	–	–	–	–	–
17.	–	–	–	–	–	–	–	S	D	F	–	–	–
18.	–	–	–	–	–	–	S	WD	S	–	–	–	–
19.	–	–	–	–	–	–	–	–	–	–	–	S	–
20.	–	–	–	–	–	–	S	WD	–	–	–	–	–
21.	–	–	–	–	–	–	S	S	–	–	–	–	–
22.	–	–	–	–	D	–	–	–	–	–	–	–	–
23.	–	–	–	–	–	–	–	–	–	–	–	–	–
Tot. taxa:	**2**	**3**	**2**	**2**	**3**	**6**	**10**	**13**	**10**	**9**	**1**	**6**	**3**

drought. Water at that time was extremely low and this provided the opportunity to obtain samples of the local fauna with comparatively little effort at most sites. Bivalve mollusks in the basins of the upper Kansas were, in general, not numerous at most collection sites. In an effort to conserve the resource, live specimens were retained only when fresh or recent empty shells of a given taxon were unavailable at a site. Thus, very few live specimens were collected during this study, however, the presence of live specimens, if they were not retained, was noted in site-specific field notes at relevant collection sites. Subfossil or chalky valves and weathered shells were actively sought for the purpose of identifying taxa no longer living in the region and to document the extent of past distributions. In a further effort to identify former ranges, dry stream sites were sampled for subfossil specimens.

Collecting sites were recorded on USGS maps with a scale of 1:250,000, and collecting conditions and notes relevant to unionid habitat were recorded at each site in a field journal. A photographic record was also made at most productive collection sites. All specimens collected were identified and the condition of each specimen was noted on site-specific collection sheets. The identifications of specimens collected prior to 1985 have, in most instances, been corroborated by Dr. David H. Stansbery of the Museum of Biological Diversity at Columbus, Ohio, while later collections have been identified solely by the author.

Voucher specimens documenting this survey have been deposited at the Museum of Biological Diversity in Columbus, Ohio. The nomenclature employed in this report is that utilized by the Museum of Biological Diversity.

Table 1. Continued.

	Smoky Hill River tributaries, continued												
	Turkey Creek			Fossil Lake	Big Creek						Ladder Creek		
Sites:	12	13	14	31	33	34	35	36	37	38	51	52	53
Year:	1983	1983	1983	1983	1983	1983	1983	1983	1983	1983	1983	1983	1983
1.	–	–	–	–	–	–	–	–	L	–	–	–	–
2.	WD	R	F	S	L	L*	L	R	–	F	L	L	–
3.	WD	–	–	–	–	–	WD	–	–	–	–	–	–
4.	S	S	–	–	–	–	–	–	–	–	–	–	–
5.	–	WD	–	–	–	–	–	–	–	–	–	–	–
6.	–	–	–	–	–	–	–	–	–	–	–	–	–
7.	–	R	–	WD	L	L*	L	–	R	–	–	–	–
8.	–	–	–	–	–	–	–	–	–	–	–	–	–
9.	–	–	–	–	–	–	–	–	–	–	–	–	–
10.	S	WD	–	–	–	–	–	–	–	–	–	–	–
11.	–	–	–	D	–	–	L	S	–	–	L	–	S
12.	–	–	–	–	–	–	–	–	–	–	–	–	–
13.	–	–	–	–	–	–	–	–	–	–	–	–	–
14.	–	–	–	–	–	–	–	–	–	–	–	–	–
15.	–	–	–	–	L	–	–	–	–	–	–	–	–
16.	–	–	–	–	–	–	–	–	–	–	–	–	–
17.	S	WD	–	–	S	–	–	–	–	–	–	–	–
18.	–	–	–	–	–	–	–	–	–	–	–	–	–
19.	–	–	–	–	–	–	–	–	–	–	–	–	–
20.	–	–	–	–	–	–	–	–	–	–	–	–	–
21.	–	–	–	–	–	–	–	–	–	–	–	–	–
22.	–	–	–	–	–	–	–	–	–	–	–	–	–
23.	–	–	–	–	–	–	–	–	–	–	–	–	–
Tot. taxa:	**5**	**6**	**1**	**3**	**4**	**2**	**4**	**2**	**2**	**1**	**2**	**1**	**1**

RESULTS

A total of 269 sites were collected during the course of this survey (Map 2) in Kansas and Nebraska. Live unionids or empty shells were obtained from 184 of these sites, 68% of the sites sampled (Map 3). Identifiable unionid mollusks were recovered at 175 locations, while only unidentifiable unionid shell fragments were recovered from the remaining nine productive sites. Non-productive collection sites (Map 4) were heavily concentrated in the extreme western portion of the study area, as were sites which produced only unidentifiable fragments. In addition, 21 locales in the western Smoky Hill Basin as well as dozens of potential sites in the Republican Basin were visited but not collected, primarily due to the absence of suitable habitat resulting from heavy grazing activities or the desiccation and subsequent overgrowth of stream substrates, and all of these sites were located in the western portion of the study area.

The distributions of bivalves recovered in this survey are discussed in detail below and have been referenced to the accompanying distribution maps. Circles and triangles on these maps indicate sites collected in this survey, with closed circles and triangles denoting sites at which a particular bivalve was recovered. The order of these maps as well as all tables in this article follows Stansbery and Borror (1983).

Twenty-one unionids and the introduced bivalve *Corbicula fluminea* were collected in this survey of the Upper Kansas Basin (Tables 1–4). All of these bivalves were present in the Smoky Hill Basin proper, however, the unionid fauna of the tributary Saline and Solomon basins as well as that of the Republican Basin were considerably less diverse. Three unionids are first reported from the Upper Kansas Basin in this study. All of these—*Obovaria olivaria*, *Truncilla donaciformis*, and *Lampsilis ventricosa*—were recovered only in weathered or subfossil condition. One taxon, *Fusconaia*

Table 2. Unionid mollusks collected from the Saline River Basin by collection site. L = live; F = fresh dead; R = recent shell; D= dry shell; WD = weathered shell; S = subfossil or chalky shell. An asterisk (*) indicates live specimen noted but not retained. Arrangement of taxa follows Stansbery and Borror (1983). All specimens were collected in 1983.

	Saline River mainstem									
Collection sites:	56	57	58	59	61	66	67	68	72	73
Taxa collected [map number]										
1. *Pyganodon grandis grandis* [6]	–	–	–	S	–	–	–	WD	–	–
2. *Anodontoides ferussacianus* [7]	–	–	–	–	–	–	–	–	–	–
3. *Lasmigona complanata* [9]	D	L*	–	–	–	–	–	–	–	–
4. *Tritogonia verrucosa* [10]	–	–	–	S	–	–	–	–	–	–
5. *Quadrula quadrula* [11]	S	L	L*	L*	L*	L	–	–	–	–
6. *Quadrula p. pustulosa* [12]	S	–	S	–	–	–	–	–	–	–
7. *Fusconaia flava* [14]	–	–	–	–	–	–	–	–	–	–
8. *Uniomerus tetralasmus* [15]	–	–	–	–	–	–	–	–	–	–
9. *Obovaria olivaria* [16}	S	–	–	–	–	–	–	–	–	–
10. *Leptodea fragilis* [17]	D	L*	L*	D	–	–	–	–	–	–
11. *Potamilus ohiensis* [18]	L	L*	L*	D	D	–	–	–	–	–
12. *Toxolasma parvus* [19]	S	–	–	–	–	–	–	D	–	–
13. *Ligumia subrostrata* [20]	–	–	–	–	–	–	–	–	–	–
14. *Lampsilis teres* f. *teres* [21]	S	–	S	S	–	–	–	–	–	–
15. *Corbicula fluminea* [24]	–	–	–	–	–	–	D	L*	–	–
16. Unidentifiable Unionid Taxa	–	–	–	–	–	–	–	–	S	S
Total taxa collected:	**8**	**4**	**5**	**6**	**2**	**1**	**1**	**3**	**1**	**1**

Table 3. Unionid mollusks collected from the Solomon River Basin by collection site. L = live; F = fresh dead; R = recent shell; D = dry shell; WD = weathered shell; S = subfossil or chalky shell. An asterisk (*) indicates live specimen noted but not retained. Arrangement of taxa follows Stansbery and Borror (1983).

	Solomon River mainstem									
Collection Sites:	80	81	85	86	88	89	90	91	94	95
Year(s) Collected:	1983	1983	1983	1983	1983	1983	1983	1983	1983	1983
Taxa collected [map number]										
1. *Pyganodon grandis grandis* [6]	–	–	–	R	–	–	S	–	D	L
2. *Anodontoides ferussacianus* [7]	–	–	–	–	–	–	–	–	–	–
3. *Strophitus u. undulatus* [8]	–	–	–	–	S	–	–	–	–	–
4. *Lasmigona complanata* [9]	L*	–	L*	L*	L*	–	D	–	–	–
5. *Tritogonia verrucosa* [10]	–	S	–	–	–	–	–	–	–	–
6. *Quadrula quadrula* [11]	L	S	D	L*	L*	WD	D	L	–	WD
7. *Quadrula p. pustulosa* [12]	S	S	–	–	L	–	L	L	–	–
8. *Fusconaia flava* [14]	–	–	–	–	S	–	–	–	–	–
9. *Uniomerus tetralasmus* [15]	–	–	–	–	–	–	–	–	–	–
10. *Obovaria olivaria* [16]	S	S	–	–	–	–	–	–	–	–
11. *Leptodea fragilis* [17]	R	D	L	L*	L*	L	L	D	D	D
12. *Potamilus ohiensis* [18]	L*	D	L*	R	L*	–	D	D	L	L*
13. *Toxolasma parvus* [19]	–	–	–	–	–	–	–	–	–	–
14. *Lampsilis teres* f. *teres* [21]	–	S	–	–	–	–	S	–	–	–
Total Taxa Collected :	**6**	**7**	**4**	**5**	**7**	**2**	**7**	**4**	**3**	**4**

Table 2. Continued

	Saline R. mainstem, cont.			Saline River tributaries					
				Mulberry Creek	Spillman Creek	Wolf Creek		Paradise Creek	
Sites:	74	77	79	55	60	63	65	70	71
1.	–	–	–	L*	WD	WD	S	–	–
2.	–	D	S	–	–	–	S	WD	WD
3.	–	–	–	–	–	–	–	–	–
4.	–	–	–	–	–	–	–	–	–
5.	S	–	–	–	–	D	–	S	–
6.	–	–	–	–	–	–	–	–	–
7.	–	–	–	S	–	–	–	–	–
8	–	L	S	S	D	D	–	R	WD
9.	–	–	–	–	–	–	–	–	–
10.	–	–	–	–	–	–	–	–	–
11.	–	–	–	–	–	–	–	–	–
12.	–	R	–	–	–	–	–	–	–
13.	–	–	–	–	–	–	S	–	–
14.	–	–	–	–	–	–	–	–	–
15.	–	–	–	–	–	–	–	–	–
16.	–	–	–	–	–	–	–	–	–
Tot. taxa:	**1**	**3**	**2**	**3**	**2**	**3**	**3**	**3**	**2**

Table 3. Continued.

	Solomon River tributaries								
	Pipe Creek	Limestone Creek		Oak Creek		South Fork Solomon R.			
Sites:	87	92	93	109	110	96	97	98	99
Year:	1983	1983	1983	1983	1983	1983	1983	1983	1983
1.	L*	L	WD	–	–	–	–	L	L
2.	–	WD	–	–	–	–	–	–	–
3.	–	–	–	–	–	–	–	–	–
4.	D	R	WD	–	–	–	–	–	–
5.	–	–	–	–	–	–	–	–	–
6.	L*	–	WD	–	–	L	L*	L	L
7.	–	–	–	–	–	L	S	–	S
8.	–	–	–	–	–	–	–	–	–
9.	WD	L*	D	L	WD	–	–	–	–
10.	–	–	–	–	–	–	–	–	–
11.	D	WD	–	–	–	–	D	L*	R
12.	–	–	–	–	–	–	L*	L*	R
13.	–	–	–	–	–	–	–	–	–
14.	–	–	–	–	–	–	–	–	–
Tot. taxa:	5	5	4	1	1	2	4	4	5

flava, previously reported by Aughey (1877) for the Republican Basin, though not recovered in that area, was represented at several sites in the Smoky Hill system by specimens in excellent condition, indicating the probable presence of live populations. The recovery of specimens of *Fusconaia flava* is noteworthy in that it is under review for possible inclusion in the Kansas list of endangered and threatened species.

In addition to the new records for the Upper Kansas Basin as a whole, a large number of new records were documented for each of its rivers. The recovery of vouchers for *Anodonta imbecillis*, *Strophitus u. undulatus*, and *Amblema plicata plicata* represent the first published records of these unionids from the study area in more than 90 years.

Only 13 of the 21 unionids recovered were represented by live specimens or by shells in recent or fresh condition. Survey results suggest that three of these unionids are now restricted to the extreme eastern portion of the Smoky Hill Basin. *Strophitus u. undulatus*, *Ligumia subrostrata*, and *Fusconaia flava* were collected as recent shells only on Lyon Creek, which is near the juncture of the Smoky Hill and Republican rivers. Ten unionids and the bivalve *Corbicula fluminea* appear to be generally holding their own to one degree or another within the Upper Kansas Basin. These are discussed in more detail below.

Utterbackia imbecillis (Map 5) was recovered from only 4 sites in the Republican and Smoky Hill basins in this study. It was collected from mud substrates in quiet water in area creeks and reservoirs. One live specimen was collected from Big Creek in the central portion of the Smoky Hill Basin, where it was reported by Scammon (1906). *Utterbackia imbecillis* is probably more widespread in the region than is indicated in this study, as its favored habitat, the quiet waters of ponds and lakes, was not extensively sampled in this survey.

Pyganodon g. grandis (Map 6) was the most frequently encountered bivalve in the Upper Kansas Basin, where it was collected at 93 sites, or 51% of all productive sites. It was present in virtually all habitats examined in this study and was the most common unionid encountered in reservoir habitats and also the most widespread unionid collected in creeks in the region. It is the only bivalve reported in the literature for the Colorado portion of the Upper Republican Basin (Brandauer and Wu 1978; Ellis 1916; Hermann and Fajt 1985).

Anodontoides ferrussacianus (Map 7) was collected at 29 of the 184 productive collection sites in this study, and specimens were obtained from each of the major

Table 3. Continued.

	Solomon River tributaries, continued											
	South Fork Solomon R., cont.					North Fork Solomon River						
Sites:	100	101	102	103	104	111	112	113	114	115	122
Year:	1983	1983	1983	1983	1983	1983	1983	1983	1983	1983	1986
1.	L*	WD	L	R	–	–	–	–	–	WD	–
2.	–	–	–	–	–	–	–	–	–	–	S
3.	–	–	–	–	–	–	S	–	–	–	–
4.	–	–	–	–	–	–	S	–	–	–	–
5.	–	–	–	–	–	–	–	–	–	–	–
6.	–	–	–	–	–	L	L*	D	–	–	–
7.	–	–	–	–	–	D	S	–	–	–	–
8.	–	–	–	–	–	–	–	–	–	–	–
9.	–	–	–	–	S	S	–	–	–	–	–
10.	–	–	–	–	–	–	–	–	–	–	–
11.	–	–	–	–	–	L	L*	D	–	–	–
12.	L*	–	–	–	–	L*	L*	–	WD	R	–
13.	–	–	–	R	–	–	–	–	–	–	–
14.	–	–	–	–	–	–	–	–	–	–	–
Tot. taxa:	**2**	**1**	**1**	**2**	**1**	**5**	**6**	**2**	**1**	**2**	**1**

Table 4. Unionid mollusks collected from the Republican River Basin by collection site. L = live; F = fresh shell; R = recent shell; D = dry shell; WD = weathered shell; S = subfossil or chalky shell. Arrangement of taxa follows Stansbery and Borror (1983).

	Republican River mainstem										
Collection site:	124	126	127	128	135	137	143	144	157	158	164
Year(s) collected:	1988 1997	1997	1997	1997	1997	1997	1997	1997	1997	1997	1997
Taxa collected [map number]											
1. *Utterbackia imbecillis* [5]	–	–	–	–	–	–	–	–	–	–	–
2. *Pyganodon grandis grandis* [6]	–	–	R	S	–	–	–	S	D	–	–
3. *Anodontoides ferussacianus* [7]	–	–	–	–	–	–	–	–	–	–	–
4. *Lasmigona complanata* [9]	–	–	–	–	–	–	–	–	–	–	–
5. *Quadrula quadrula* [11]	–	–	L	–	–	–	–	–	–	–	–
6. *Quadrula pustulosa pustulosa* [12]	–	–	–	–	–	–	–	–	–	–	–
7. *Uniomerus tetralasmus* [15]	–	–	–	–	–	–	–	–	S	–	–
8. *Obovaria olivaria* [16]	S	–	–	S	–	–	–	–	–	–	–
9. *Leptodea fragilis* [17]	L	–	R	–	F	–	F	WD	R	F	–
10. *Potamilus ohiensis* [18]	–	D	L	F	WD	S	F	D	S	F	WD
11. *Toxolasma parvus* [19]	–	–	–	–	–	–	–	–	–	–	–
12. *Ligumia subrostrata* [20]	–	–	S	S	–	–	–	–	–	–	–
13. *Lampsilis teres* f. *teres* [21]	–	–	–	S	–	–	–	–	S	–	–
14. *Lampsilis radiata luteola* [22]	–	–	–	–	–	–	–	–	–	–	–
15. *Lampsilis ventricosa* [23]	–	–	–	–	–	–	–	–	–	–	–
16. *Corbicula fluminea* [24]	F	F	–	–	–	–	–	–	–	–	–
17. Unidentifiable fragments	–	–	–	–	–	–	–	–	–	–	–
Total taxa collected:	**3**	**2**	**5**	**5**	**2**	**1**	**2**	**3**	**5**	**2**	**1**

river basins in the region. Specimens in good condition were obtained from 13 sites. Nine sites were in the central portions of the Smoky Hill River, the tenth in the upper Saline River and the remainder in the Upper Republican Basin in Nebraska. At several collection sites in the Smoky Hill River in Russell, Trego and Ellis counties, *Anodontoides ferrussacianus* was the most common bivalve recovered. Many fresh dead specimens were recovered from portions of the Smoky Hill which had apparently been recently opened up to grazing in 1983, as indicated by the condition of vegetation at those sites. The documentation of extant populations of this species in Kansas is noteworthy in that it is under review for possible inclusion in the Kansas list of Endangered and Threatened species.

Lasmigona complanata (Map 9) was found in all three rivers in the Smoky Hill system, but was most widespread in the Solomon River. This bivalve, when present, was never the most abundant bivalve at any collection site. It was recovered from both creek and river habitats and was represented in each almost equally. Though not collected in the Republican River, *L. complanata* was present in creeks within the Republican Basin.

The second most common unionid encountered in this survey was *Quadrula quadrula* (Map 11), which was collected at 73 collection sites. This bivalve was common in all of the rivers in the Smoky Hill Basin, but it was rare in the Republican River. In addition, it was common in the region's creeks, with a distribution which extends throughout the eastern and central portions of the Smoky Hill system, and into the upper portion of the Republican Basin.

The distribution of *Quadrula p. pustulosa* (Map 12) was confined to the Smoky Hill system. Live specimens were rare in the eastern portion of the Smoky Hill and Saline basins, and, with the exception of site 18, all specimens found in these basins were in weathered or subfossil condition. In contrast, its distribution in the Solomon River Basin extended well into the central portion of the survey area, and live specimens were found as far west as site 99.

Uniomerus tetralasmus (Map 15) was found in creeks and creek-like habitats throughout the study area. It was also present occasionally in many of the region's rivers. This bivalve was collected from the western-most productive collection sites in both the Smoky Hill and Saline basins. This would appear to

Table 4. Continued.

	Republican River mainstem, continued												
Sites:	168	169	170	171	177	190	191	229	254	256	257	258	265
Year(s):	1997	1997	1997	1997	1997	1990	1990	1990	1990	1990	1990	1990	1990
1.	–	–	–	–	R	–	–	–	–	–	–	–	–
2.	–	–	–	–	R	S	D	–	L	R	L	–	–
3.	–	–	–	–	–	S	–	–	–	–	–	–	–
4.	–	–	–	–	–	–	–	–	–	–	–	–	–
5.	–	–	–	–	–	–	–	–	–	–	–	–	–
6.	–	–	–	–	–	–	–	–	–	–	–	–	–
7.	–	–	D	S	–	S	–	S	–	–	–	D	–
8.	S	–	–	–	–	–	–	–	–	–	–	–	–
9.	R	D	–	–	–	–	–	–	–	–	–	–	–
10.	WD	WD	WD	D	R	L	D	–	–	–	–	–	–
11.	–	–	–	–	–	–	–	–	–	–	–	–	–
12.	–	–	–	–	–	–	–	–	–	–	–	–	–
13.	–	–	–	–	–	–	–	–	–	–	–	–	–
14.	–	–	–	–	–	–	–	–	–	–	–	–	–
15.	–	–	–	–	–	–	–	–	–	–	S	–	–
16.	–	–	–	–	–	–	–	–	–	–	–	–	–
17.	–	–	–	–	–	–	–	–	–	–	–	–	S
Tot. taxa:	**3**	**2**	**2**	**2**	**3**	**4**	**2**	**1**	**1**	**1**	**2**	**1**	**1**

reflect its well known ability to withstand conditions too harsh for other unionids. It was even more common in the Republican Basin. Live populations were found as far west as Ladder Creek in the Smoky Hill Basin, in the extreme upper reaches of the Saline River at site 79, and in the Republican Basin as far west as site 250.

Leptodea fragilis (Map 17) was collected at 50 sites in the Upper Kansas Basin and was the fifth most common unionid recovered during the survey. Live populations were found in each of the region's rivers, and in area creeks as well. It was often quite numerous when found. It is one of only four unionids recovered live or in good condition from the lower portion of the Republican River.

Potamilus ohiensis (Map 18) was the third-most frequently encountered bivalve in this survey with live populations in each of the major area rivers. In addition it was the second-most common bivalve in study area reservoirs, and was also present in local creeks. When present, it was often the most numerous bivalve. Its distribution is similar to that of *Leptodea fragilis*, however, it extends somewhat farther west in the Solomon and Saline basins and much farther west in the Smoky Hill and Republican basins.

Toxolasma parvus (Map 19) was widespread in its distribution but infrequently recovered and never numerous. It was collected at only six sites but is probably more common than is suggested from the results of this study. Due to its small size it is easy to overlook this bivalve. It was collected live or as an empty shell in good condition at several sites in the Saline, Solomon, and Republican basins.

In addition, a large living population of the introduced bivalve *Corbicula fluminea* (Map 24) was discovered in Wilson Lake, a reservoir on the Saline River. Additional populations were located in reservoirs on the Smoky Hill and Republican rivers, and specimens were recovered from below Milford Reservoir on the Republican River in Kansas as well.

The remaining eight unionid taxa were collected only as weathered or chalky empty shells. *Tritogonia verrucosa*, *Amblema plicata plicata*, *Truncilla donaciformis*, and *Lampsilis teres* f. *anodontoides* were limited in their distributions to the extreme eastern portion of the Smoky Hill system. Two other unionids, *Lampsilis radiata luteola* and *L. ventricosa*, though extremely uncommon, were geographically widely distributed. This is similar to the pattern of their distri-

Table 4. Continued.

	Republican River tributaries														
	Five Creek	Parson's Creek		Elm Creek	West Creek			Wolf Creek		Buffalo Creek					
Sites:	129	133	134	139	140	141	142	145	146	147	151	152	153	154	155
Year(s):	1997	1996	1996	1997	1996	1996	1996	1996	1996	1996	1996	1996	1996	1996	1996
1.	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
2.	WD	S	WD	WD	D	R	–	WD	–	WD	F	L	D	R	WD
3.	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
4.	–	–	WD	–	–	–	–	–	–	R	WD	–	–	–	–
5.	–	D	R	–	L	–	–	–	–	S	WD	–	–	–	–
6.	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
7.	S	–	–	–	–	–	R	D	R	–	WD	–	–	R	–
8.	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
9.	–	–	–	–	–	–	–	–	–	R	R	–	–	–	–
10.	–	–	–	–	D	–	–	–	–	–	F	–	–	–	–
11.	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
12.	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
13.	–	–	–	–	S	–	–	S	–	S	–	–	–	–	–
14.	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
15.	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
16.	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
17.	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Tot. taxa:	**2**	**2**	**3**	**1**	**4**	**1**	**1**	**3**	**1**	**5**	**6**	**1**	**1**	**2**	**1**

butions within the Platte system in Nebraska (Hoke 1995). The remaining two taxa, *Obovaria olivaria* and *Lampsilis teres* f. *teres*, were relatively widely distributed and present at a fair number of sites, and may once have been relatively common in the eastern portion of the survey area. *Obovaria olivaria* has not been reported as a live record in Kansas since Scammon (1906) reported it from the Kansas River near Topeka.

Species diversity was heavily concentrated in the eastern portion of the study area, and most sites in this area were productive. Unionids were rarely encountered in the western third of the basin, due to a near total absence of stream flow in this region. Dewatering and over-grazing of riparian habitat are significant factors restricting bivalve distributions in the region.

PREVIOUS LITERATURE

Published material on the bivalve mollusks of the upper Kansas basin is extremely limited. In most instances, it consists of reports of limited numbers of records contained within more comprehensive works. The earliest of these publications was that of Aughey (1877) who reported six taxa for the Nebraska portion of the Republican Basin. Since two of Aughey's taxa are synonyms for *Ligumia subrostrata*, Aughey actually noted only five currently recognized taxa for the basin. Only three of these—*Pyganodon g. grandis*, *Fusconaia flava*, and *Ligumia subrostrata*—appear to be valid records. The two remaining records, those for *Elliptio complanata* (Lightfoot, 1786) [as *Unio quadratus* (Lea)] and *Epioblasma torulosa gubernaculum* (Reeve, 1865) [as *U. gubernaculum* (Reeve)], appear to be misidentifications. Burch (1975) reports *Elliptio complanata* for the Atlantic coastal and Great Lakes regions. *Epioblasma torulosa gubernaculum* also appears to be highly suspect. In the absence of corroborating reports or vouchers for these taxa, they are assumed to be misidentifications.

In Kansas, most of the published records for the Smoky Hill system are those of Call (1885a, 1885b, 1885c, 1887) and Scammon (1906), and consist of reports of scattered vouchers often supplied to those authors by correspondents. Call reported *Pyganodon g. grandis*, *Anodontoides ferussacianus*, *Lasmigona complanata*, *Quadrula quadrula*, *Q. p. pustulosa*, *Uniomerus tetralasmus*, *Toxolasma parvus*, *Ligumia recta* (Lamarck, 1819), and *L. subrostrata* from the Smoky Hill system, and added *A. ferussacianus* and *U. tetralasmus* to those taxa reported from the Republican

Table 4. Continued.

	Republican River tributaries, continued														
	West Marsh Creek		White Rock Cr.		Courtland Canal			Turkey Creek	Prairie Dog Creek						
Sites:	148	150	161	162	165	166	167	175	178	179	182	183	184	186	187
Year(s):	1996	1996	1994	1994	1996	1996	1996	1997	1990	1990	1990	1990	1990	1990	1990
1.	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
2.	S	–	–	–	–	WD	R	–	WD	–	–	–	–	–	–
3.	–	–	–	–	–	–	–	–	–	–	–	–	–	S	–
4.	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
5.	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
6.	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
7.	L	D	L	D	D	–	–	–	–	R	–	S	D	S	S
8.	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
9.	–	–	–	–	–	WD	R	–	–	–	–	–	–	–	–
10.	–	–	–	–	WD	D	R	–	–	–	–	–	–	–	–
11.	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
12.	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
13.	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
14.	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
15.	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
16.	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
17.	–	–	–	–	–	–	–	S	–	–	S	–	–	–	–
Tot. taxa:	**2**	**1**	**1**	**1**	**2**	**3**	**3**	**1**	**1**	**1**	**1**	**1**	**1**	**2**	**1**

Basin by Aughey (1877).

Scammon (1906) specifically mentioned fourteen unionids for the Smoky Hill system and two from the Republican Basin. In addition to most of the species listed by Aughey (1877) and Call (1885a, 1885b, 1885c, 1887), Scammon first reported *Utterbackia imbecillis*, *Strophitus u. undulatus*, *Tritogonia verrucosa*, *Amblema plicata plicata*, *Leptodea fragilis*, *Potamilus alatus* (Say, 1817), *P. purpuratus*, and *P. ohiensis* for the Smoky Hill system. Scammon does not specifically mention *Anodontoides ferussacianus*, or *Quadrula p. pustulosa*, for the Smoky Hill system, although his statements on the distributions of those species could include the Smoky Hill system, and he specifically excludes *Ligumia recta* from the Upper Kansas Basin.

An analysis of Murray and Leonard's (1962) distribution maps indicates that they regarded only ten taxa as validly reported from the region. In addition to *Ligumia recta*, these authors excluded *Utterbackia imbecillis*, *Anodontoides ferussacianus*, *Quadrula p. pustulosa*, *Amblema plicata plicata*, *Leptodea fragilis*, *Potamilus alatus*, and *P. purpuratus* from their Upper Kansas distributions.

Other literature on the Upper Kansas Basin has served primarily to confirm the validity of the earlier records or to extend the known ranges of species previously reported. The only taxa added to those reported through the early part of the twentieth century are *Lampsilis teres anodontoides* and *L. radiata luteola*, collected from the Smoky Hill Basin (Miller and Hibbard 1972) and *L. teres teres*, which has been collected from the Republican Basin (Schuster and Dubois 1979).

Thus, prior to the current study, a total of 23 unionids were reported for the Upper Kansas Basin, of which two, reported by Aughey (1877), are almost certainly in error. A summary of all of the published records for the Upper Kansas Basin appears in Table 5.

The results of this survey compare favorably to those reported in the literature. Eighteen of those unionids previously reported for the region were recovered in this survey. In addition, three unionids are first reported for the Upper Kansas basin in this paper, as well as the introduced bivalve *Corbicula fluminea*. *Potamilus alatus*, *P. purpuratus* and *Ligumia recta*, previously reported, were not collected in this survey;

Table 4. Continued.

	Republican River tributaries, continued										
	Methodist Creek	**Sappa Creek**		**Beaver Creek**			**Muddy Creek**				**Deer Creek**
Sites:	189	193	194	199	201	203	207	208	210	211	214
Year(s):	1990	1990	1990	1990	1990	1990	1990	1990	1990	1972	1990
1.	–	–	–	–	–	–	–	–	–	–	–
2.	D	D	–	–	–	S	–	R	–	–	–
3.	–	–	–	–	–	–	–	–	–	–	–
4.	–	–	–	–	WD	–	–	–	–	–	–
5.	S	D	–	–	–	–	R	R	L	–	–
6.	–	–	–	–	–	–	–	–	–	–	–
7.	–	–	–	D	–	–	–	–	–	L	L
8.	S	–	–	–	–	–	–	–	–	–	–
9.	–	–	–	–	–	–	–	–	–	–	–
10.	D	R	–	–	–	–	–	–	–	–	–
11.	–	–	–	–	–	–	–	–	–	L	–
12.	–	–	–	–	–	–	–	–	–	–	–
13.	–	–	–	–	–	–	–	–	–	–	–
14.	–	–	–	–	–	–	–	–	–	–	–
15.	S	–	–	–	–	–	–	–	–	–	–
16.	–	–	–	–	–	–	–	–	–	–	–
17.	–	–	S	–	–	–	–	–	–	–	–
Tot. taxa:	**5**	**3**	**1**	**1**	**1**	**1**	**1**	**2**	**1**	**2**	**1**

however the first two species were collected by Schuster and Dubois (1979). *Ligumia recta* has been recovered by the author from the nearby Big Blue River, which should serve to support Call's (1885c) report for this species on the Solomon River.

Prior to this study, many of the unionids of the Upper Kansas Basin were known from only a few widely scattered collection sites, and the regional distributions of these animals were incomplete. In fact, in some basins the unionid fauna was almost unknown. This was particularly true of the Saline and Republican basins. There are only three previous published records from the Saline Basin, documenting two unionids. In contrast, fourteen unionids were documented for that system in this study as well as the introduced bivalve *Corbicula fluminea*.

For that portion of the Republican Basin within Nebraska, only three probable taxa had been reported in previous literature, while this survey confirmed two of the early records and documented an additional eleven species. In addition, the study first documented eight unionids for the Solomon Basin; seven for the entire Republican Basin; and four in the Smoky Hill Basin.

DISCUSSION

The unionids of the Upper Kansas Basin are subject to severe natural and man-made constraints upon their distributions and abundance. Natural constraints include the limited diversity of habitats and the unavailability of contant flows of water to support bivalve life. Man-made constraints include the extent of surface and subsurface water withdrawals for irrigation and other purposes, reservoir construction, unrestricted grazing, pollution and siltation.

Habitat diversity in the Upper Kansas Basin rivers is extremely limited. Most reaches of the rivers are shallow, relatively wide, and characterized by sand substrates. This type of environment supports limited numbers and species of host fish and related bivalves. An even more detrimental habitat in the region is the presence of shifting sand substrates, a habitat known to be detrimental to unionids. While most sections of all of the rivers in the Upper Kansas Basin have sand substrates, not all of them have shifting sand substrates. It is primarily along the Republican River that the substrates may truly be described as shifting sand. A comparison of the species occurrences for river habitats (Table 6) between the Smoky Hill system and the

Table 4. Continued.

	Republican River tributaries, continued													
	Medicine Creek										Red Willow Creek			
Sites:	216	217	218	219	220	221	223	224	227	228	234	235	237	238
Year(s):	1990	1990	1972	1972 1981	1990	1990	1990	1990	1990	1972	1990	1990	1990	1972 1891 1990
1.	–	–	D	L	–	–	–	–	–	–	–	–	–	–
2.	R	WD	–	L	R	R	–	L	R	D	L	R	L	L
3.	–	–	–	–	–	–	R	L	–	–	–	–	–	–
4.	–	–	–	–	S	R	–	–	–	–	–	–	L	L
5.	–	L	–	–	S	S	–	L	–	–	–	–	–	D
6.	–	–	–	–	–	–	–	–	–	–	–	–	–	–
7.	–	–	–	L	S	–	R	–	–	–	–	–	–	L
8.	–	–	–	–	–	–	–	–	–	–	–	–	–	–
9.	–	–	–	–	–	–	–	–	–	–	–	–	–	–
10.	–	–	–	–	–	–	–	–	–	–	–	–	–	–
11.	–	–	–	–	–	–	–	–	–	–	–	–	–	–
12.	–	–	–	–	S	–	–	–	–	–	–	–	–	–
13.	–	–	–	–	–	–	–	–	–	–	–	–	–	–
14.	–	–	–	S	–	–	–	–	–	–	–	–	–	–
15.	–	–	–	–	–	–	–	–	–	–	–	–	–	–
16.	–	–	–	–	–	–	–	–	–	–	–	–	–	–
17.	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Tot. taxa:	**1**	**2**	**1**	**4**	**5**	**3**	**2**	**3**	**1**	**1**	**1**	**1**	**2**	**4**

Republican Basin reveals unionid diversity to be much greater in the stable sand substrates of the former than in the shifting sand substrates of the latter. Unionids in the Republican River are infrequent and limited to only a few species, of which *L. fragilis* and *P. ohiensis* are by far the most numerous. The rivers in the Smoky Hill system, in contrast are characterized by relatively stable sand bottoms, and this habitat can support unionids in greater abundance and diversity than is the case in the Republican River. These unionids include *Pyganodon g. grandis*, *Anodontoides ferussacianus*, *Lasmigona complanata*, *Quadrula quadrula*, *Q. p. pustulosa*, and *Toxolasma parvus*, in addition to those unionids found in the Republican River.

While Upper Kansas Basin rivers offer a relatively uniform habitat, with largely sand or shifting sand substrates, their tributary creeks provide diverse habitats including stable sand and mud substrates and occasional rock-riffle areas. Portions of many of these creeks contain deeper pools and have steadier flows than do area rivers. Further, water temperatures are often lower in these creeks than in area rivers.

The muddy substrates of some of these creeks provide important habitat for *Utterbackia imbecillis*, *Pyganodon g. grandis*, *Quadrula quadrula*, and *Uniomerus tetralasmus* throughout the region. In fact, as shown in Table 6, the three latter species are more common there than in area rivers. In addition, creeks offer habitat for some bivalves that might not otherwise survive in the area. In effect, some of these creeks serve as refugia. This pattern is most pronounced in the Upper Republican Basin, where almost no unionids are found in rivers. In that region, local creeks provide the primary habitat for unionids. A similar distribution has been reported for the Elkhorn and Platte basins in Nebraska by Hoke (1994, 1995).

Certain creeks also provide habitat for bivalves that may otherwise be far from their natural ranges. Thus, the western-most records for *Ligumia subrostrata*, *Lampsilis radiata luteola*, and, with one exception, *L. ventricosa*, are located in creek habitat. Creeks continue to be important to the unionid diversity of the region as is evident from the restriction of live *Strophitus u. undulatus*, *Fusconaia flava*, and *Ligumia subrostrata* to that habitat in the lower Smoky Hill Basin.

Further, within these tributaries only certain reaches provide the habitat which is critical to the maintenance of unionid populations in the region. The

Table 4. Continued.

	Republican River tributaries, continued									
	Frenchman River						Muddy Creek	South Fork	Rock Creek	Arikaree River
Sites:	246	247	248	249	250	251	260	263	267	269
Year(s):	1990	1990	1990	1972 1981	1990	1990	1972 1981	1990	1972 1981	1990
1.	–	–	–	–	–	–	–	–	–	–
2.	L	R	R	L	L	–	–	–	L	–
3.	–	–	–	–	R	L	–	–	–	–
4.	–	–	–	–	–	–	–	–	–	–
5.	–	–	–	–	–	–	–	–	–	–
6.	–	–	–	–	–	–	–	–	–	–
7.	–	–	–	–	L	–	D	–	–	–
8.	–	–	–	–	–	–	–	–	–	–
9.	–	–	–	–	–	–	–	–	–	–
10.	–	–	–	–	–	–	–	–	–	–
11.	–	–	–	–	–	–	–	–	–	–
12.	–	–	–	–	–	–	–	–	–	–
13.	–	–	–	–	–	–	–	–	–	–
14.	–	–	–	–	–	–	–	–	–	–
15.	–	–	–	–	–	–	–	–	–	–
16.	–	–	–	–	–	–	–	–	–	–
17.	–	–	–	–	–	–	–	S	–	S
Tot. taxa:	**1**	**1**	**1**	**1**	**3**	**1**	**1**	**1**	**1**	**1**

Upper Kansas Basin receives decreasing rainfall westward. In times of severe drought, large sectors of the area's rivers as well as of its tributary creeks are subject to dewatering. Many of the species native to the area can survive for limited periods by burying themselves in the sandy substrates of the region. During extended periods of drought, however, many of these animals die. It is only along limited reaches of creeks and rivers fed by good springs which are relatively unaffected by year to year changes in precipitation, that unionid populations can be maintained. Site 162 on White Rock Creek is one of these locales. Along a 50-yard reach in 1994, over 70 live *U. tetralasmus* were located. The owner of this site noted that in times of severe drought, only a sector about 200 yards in length contains any water. It is fed by a local spring, and reaches of the creek both above and below that sector were dusty in the driest years.

The historic distributional model proposed for the Upper Kansas Basin differs from the general model for unionid species diversity, which holds that diversity is greater in larger rivers than in their tributaries. The general model presupposes that larger rivers have greater environmental diversity than their tributaries. In the Upper Kansas Basin river size often does not correlate with habitat diversity, nor does it always correlate with stability of flow. Thus, tributary streams in the Upper Kansas Basin often provide critical habitat to support unionid species diversity.

The hydrological development of the region has increased the severe pressures upon the unionid mollusks of the region. This has taken two forms. The first is the impact of surface and subsurface water withdrawal for the purpose of irrigation. The second is the impact of the construction of 14 major reservoirs in the study area.

While surface water withdrawal occurs throughout the region, its effects are most pronounced in the Nebraska sector of the Republican Basin. In this basin, the Republican River is subject to a virtual draining of water during the summer irrigation season. Site 261 on the Republican River, and 262 on the South Fork of the Republican were completely dry in 1990, despite the presence of water upstream from those locales. The volume of water in the river at site 206 was only a trickle in 1990 despite significant upstream flows. The impact of excessive water withdrawals, coupled with high temperatures and lack of rainfall, has resulted in water temperatures of nearly 100° F in portions of the

Table 5. Unionid mollusks reported from the Upper Kansas Basin. Upper-case letters denote Hoke's specimen-types: L = live; F = fresh shell; R = recent shell; D = dry shell; WD = weathered shell; S = subfossil or chalky shell. Lower case letters denote literature source: a = Aughey (1877); b = Brandauer and Wu (1978); c = Brunson (1979); d = Call (1885a, 1885b, 1885c, 1887); e = Eberle, Ernsting, and Tomelleri (1986); f = Ellis (1916); g = Hermann and Fajt (1985); h = Liechti and Huggins (1977); j = Miller and Hibbard (1972); k = Murray and Leonard (1962); l = Scammon (1906); and m = Schuster and Dubois (1979). Order of taxa follows Stansbery and Borror (1983).

	Smoky Hill System							
	Smoky Hill Basin[1]		Saline Basin		Solomon Basin		Republican Basin	
	Hoke (1997)	Prev. Reports	Hoke (1997)	Prev. Reports	Hoke (1997)	Prev. Reports	Hoke (1997)	Prev. Reports
Confirmed taxa [map number]								
Utterbackia imbecillis [5]	L	k,l	–	–	–	–	L	–
Pyganodon grandis grandis [6]	L	c,d,e,h,j, l,m	L	k,m	L	d,m	L	a,b,f,g,l
Anodontoides ferussacianus [7]	L	d,j,l?,m	D	–	WD	–	L	d,l
Strophitus undulatus undulatus [8]	F	k,l	–	–	S	–	–	–
Lasmigona complanata [9]	L	d,k	L	–	L	k,l	L	–
Tritogonia verrucosa [10]	WD	j,k,l	S	–	S	–	–	–
Quadrula quadrula [11]	L	c,d,e,h,j,k,l	L	–	L	m	L	m
Quadrula pustulosa pustulosa [12]	L	d,j,l?	S	–	L	–	–	–
Amblema plicata plicata [13]	WD	l	–	–	–	–	–	–
Fusconaia flava [14]	R	j	S	–	S	–	–	a
Uniomerus tetralasmus [15]	L	c,h,j,k	L	m	L	k,l,m	L	d
Obovaria olivaria [16]	WD	–	S	–	S	–	S	–
Truncilla donaciformis [13]	S	–	–	–	–	–	–	–
Leptodea fragilis [17]	L	j	L	–	L	l,m	L	–
Potamilus alatus	–	l,m	–	–	–	–	–	–
Potamilus purpuratus (Lamarck, 1819)	–	l	–	–	–	m	–	–
Potamilus ohiensis [18]	L	e,j,k,l,m	L	–	L	m	L	h,m
Toxolasma parvus [19]	D	d,j,k,l	R	–	R	–	L	–
Ligumia recta	–	–	–	–	–	d	–	–
Ligumia subrostrata [20]	F	d,j,k,l	S	–	–	–	S	a,d
Lampsilis teres f. *teres* [21]	WD	–	S	–	S	–	S	m
Lampsilis teres f. *anodontoides* [21]	S	j	–	–	–	–	–	–
Lampsilis radiata luteola [22]	WD	j	–	–	–	–	S	–
Lampsilis ventricosa [23]	S	–	–	–	–	–	S	–
Corbicula fluminea [24]	F	–	L	–	–	–	L	–
Total confirmed taxa by source:	**22**	**19**	**15**	**2**	**14**	**8**	**15**	**8**
Total confirmed taxa by basin:	**24**		**15**		**16**		**16**	
Probable Misidentified taxa								
Elliptio complanatus	–	–	–	–	–	–	–	a
Epioblasma torulosa gubernaculum	–	–	–	–	–	–	–	a
Total confirmed taxa by source:	**22**	**19**	**15**	**2**	**14**	**8**	**15**	**10**
Total confirmed taxa by basin:	**24**		**15**		**16**		**18**	

[1]Excludes the Saline and Solomon basins

Republican River (NGPC 1983), killing fish throughout long sections of the river. It is significant that all live unionids recovered in the Republican River above site 191 were from or directly associated with reservoirs.

Surface water withdrawal encompasses siphoning of water by individual landowners as well as the wholesale withdrawal of all or most of the flow into irrigation canals. A large diversion along the Republican River occurs when water is removed to the Courtland Canal system. Flow below that point is significantly diminished. Similar losses of flow occur in Upper Republican creeks. Of the 1,174 original stream miles in the Nebraska portion of the Republican River Basin, 453 miles or 39% have been listed as environmentally degraded due to surface water withdrawals for irrigation (NNRC

1976). Included in this category were Beaver and Sappa creeks, and portions of the Republican and Frenchman rivers, and Red Willow and Medicine Creeks.

Added to this pressure upon riparian habitats is the impact of subsurface water withdrawals upon Upper Kansas Basin stream flows. Through the use of center pivot irrigation systems and their accompanying wells, farming can now be supported on land formerly suitable only for grazing. The resultant lowering of water tables is progressively destroying remaining riparian habitat in the region, with the most severe impacts occurring in the extreme western portion of the study area. Sophocleous (1981) and Jordan (1982) discussed the deteriorating hydrological conditions in western Kansas, and Hoffman (1983b) described this process on the Frenchman River in Nebraska. Over 50% of Dundy and Chase counties on the Nebraska-Colorado border have suffered water table declines of five to over thirty feet from pre-development levels (Flowerday 1993).

The effects of these processes have been observed by the author over the past 26 years. Site 249 near Champion, Nebraska, had a good population of unionids in 1972 but was dry in 1980. Site 238 northeast of Hayes, Nebraska, which was extremely productive in both 1972 and 1980, was much diminished in size in 1990 and the site of a bivalve kill. In addition, quicksand observed at this site in both the early visits was gone in 1990, indicating the termination of an associated spring. A similar situation was documented at site 211 on Muddy Creek in 1972.

Sections of creeks lying below some area reservoirs have been subjected to significant changes in water flow from pre-development conditions, with restricted flows throughout the majority of the year and concentrated high volume flow levels for a few weeks in the late summer as water is released for irrigation. No unionids were found below Hugh Butler Lake on Red Willow Creek at any of the sites surveyed, however, area residents reported collecting unionids from this stream sector prior to the construction of the dam. Flowing sections of Red Willow Creek above the reservoir were sometimes well populated with unionids. On Medicine Creek, unionids were occasionally abundant in unmodified sectors of the stream above Harry Strunk Lake, but infrequent below the dam with the exception of the half mile immediately below the dam. The same pattern was repeated for the Frenchman River. No evidence of bivalves was recovered below Enders Reservoir, but residents reported that unionids were once present.

The impacts of water development upon unionids are not confined solely to impacts upon flow. The construction of 14 major dams in the region has submerged habitat in some of the key tributaries of the Upper Kansas Basin which formerly acted as refugia for unionids. Large portions of Medicine and Red Willow creeks are now covered by reservoir waters.

Hydrological development of the region has not been entirely detrimental to unionids. Limited but important habitat was found immediately below a number of the major and minor dams in the Upper Republican Basin. These areas are no doubt favorable due to the blockage of stream channels by the dams and the resultant concentration of host fish necessary for unionid reproduction immediately below these structures. In addition, these areas are most likely to retain some flow throughout the year unless releases from the upstream reservoir are totally curtailed. Additional lotic habitat has been created with the construction of irrigation canals in the region. Scattered unionids were reported by local residents in these canals, and one large population of *L. fragilis*, *P. ohiensis*, and *P. g. grandis* was located and collected in a sector of the Courtland Canal during this study.

Reservoir construction has provided much new habitat for unionids adaptable to a lentic environment, however, the value of this habitat is limited by the relatively large fluctuations in water depth that occur during the irrigation season. On Medicine Creek, Harry Strunk Lake may drop 6 to 8 feet in a few weeks in late summer due to release of water for irrigation activities. Only two species of unionids, *P. g. grandis*, and *P. ohiensis*, both silt tolerant, were found to be present in area reservoirs in any numbers.

Unionids are also severely impacted by unrestricted access of farm animals to streambeds in the Upper Kansas Basin. In the western reaches of the Smoky Hill system, as well as along the Arikaree River, and the upper portions of streams in the Upper Republican Basin, it was difficult to locate any riparian areas which had not been destroyed in this manner.

Evidence for the impact of pollution upon the unionids of the region is more circumstantial than direct. The Smoky Hill River in the vicinity of Salina was almost devoid of living bivalves despite the fact that water flows in this reach of the river are generally good. Unionids formerly present in the region, such as *Tritogonia verrucosa*, *Ablema plicata plicata*, *Obovaria olivaria*, and *Truncilla donaciformis*, are now absent. They have disappeared not only from the Upper Kansas Basin but also from much of their former range in northern Kansas and Nebraska (Hoke, 1996). Such a general disappearance could be the result of widespread use of herbicides or pesticides in the area.

As favorable habitat in the Upper Kansas Basin continues to be destroyed, the importance of maintain-

Table 6. Summary of unionid mollusks recovered in this survey from the Smoky Hill River System and Republican River Basin by habitat. Arrangement of taxa follows Stansbery and Borror (1983).

	SMOKY HILL RIVER SYSTEM											
	Site occurrences[1]											
	Smoky Hill R. Basin				Saline R. Basin				Solomon R. Basin			
Taxa [map number]	Riv.	Crks.	Res. & Lks.	Tot.	Riv.	Crks.	Res. & Lks.	Tot.	Riv.	Crks.	Res. & Lks.	Tot.
1. *Utterbackia imbecillis* [5]	0	1	0	1	0	0	0	0	0	0	0	0
2. *Pyganodon grandis grandis* [6]	5	15	4	24	1	4	1	6	6	3	5	14
3. *Anodontoides ferussacianus* [7]	14	2	0	16	2	3	0	5	1	1	0	2
4. *Strophitus undulatus undulatus* [8]	4	6	0	10	0	0	0	0	2	0	0	2
5. *Lasmigona complanata* [9]	3	7	0	10	2	0	0	2	6	3	0	9
6. *Tritogonia verrucosa* [10]	2	0	0	2	1	0	0	1	1	0	0	1
7. *Quadrula quadrula* [11]	13	13	4	30	7	2	0	9	15	2	1	18
8. *Quadrula pustulosa pustulosa* [12]	9	1	0	10	2	0	0	2	10	0	0	10
9. *Amblema plicata plicata* [13]	1	6	0	7	0	0	0	0	0	0	0	0
10. *Fusconaia flava* [14]	0	8	0	8	0	1	0	1	1	0	0	1
11. *Uniomerus tetralasmus* [15]	6	4	1	11	2	5	0	7	2	5	0	7
12. *Obovaria olivaria* [16]	3	0	0	3	1	0	0	1	2	0	0	2
13. *Truncilla donaciformis* [13]	2	0	0	2	0	0	0	0	0	0	0	0
14. *Leptodea fragilis* [17]	9	6	0	15	4	0	0	4	14	2	2	18
15. *Potamilus ohiensis* [18]	19	5	2	26	5	0	0	5	13	0	4	17
16. *Toxolasma parvus* [19]	1	0	0	1	2	0	1	3	0	0	1	1
17. *Ligumia subrostrata* [20]	3	6	0	9	0	1	0	1	0	0	0	0
18. *Lampsilis teres* f. *teres* [21]	4	3	0	7	3	0	0	3	2	0	0	2
19. *Lampsilis teres* f. *anodontoides* [21]	0	1	0	1	0	0	0	0	0	0	0	0
20. *Lampsilis radiata luteola* [22]	0	2	0	2	0	0	0	0	0	0	0	0
21. *Lampsilis ventricosa* [23]	1	2	0	3	0	0	0	0	0	0	0	0
22. *Corbicula fluminea* [24]	0	0	1	1	0	0	2	2	0	0	0	0
23. Unidentifiable fragments	3	0	0	3	2	0	0	2	0	0	0	0
Total taxa reported:	**102**	**88**	**12**	**202**	**34**	**16**	**4**	**54**	**75**	**16**	**13**	**104**
Sites												
A. Productive	23	19	5	47	11	6	2	19	19	5	6	30
B. Non-productive	5	1	1	7	5	1	0	6	10	4	0	14
Total Sites:	**28**	**20**	**6**	**54**	**16**	**7**	**2**	**25**	**29**	**9**	**6**	**44**

[1]The number of collection sites at which a taxon was collected.

ing remaining unionid habitat and preserving or enhancing its quality increases. This is especially true for those species not readily adaptable to the region's reservoirs. At present, the most critical unionid stream habitat in the Smoky Hill system are the lower portions of the Saline and Solomon rivers and the central reach of the Smoky Hill River as well as a number of tributary creeks including Big Creek and especially Lyon Creek. In the Republican Basin the critical habitat appears to be those sections of Medicine and Red Willow creeks lying above Harry Strunk and Hugh Butler lakes in Nebraska, minor tributaries which still retain relatively undiminished flow throughout the year, such as Muddy Creek near Arapahoe and the pools and streams immediately below area dams.

CONCLUSION

The unionid fauna of the Upper Kansas Basin once consisted of at least 24 unionid taxa. Twenty-one were documented in this survey as well as the introduced bivalve *Corbicula fluminea*. Eight unionids were collected only as weathered or subfossil empty shells. Three, formerly reported for the region, were not collected at all. This suggests a potential loss of 11 of the 24 unionids originally native to the region, or 46% of the region's unionid diversity. In addition, the ranges of at least four of the surviving bivalves appear to have contracted significantly.

Table 6. Continued.

	SMOKY HILL RIVER SYSTEM, cont.								REPUBLICAN R. BASIN							
	Site occurrences[1]				% of Productive sites[2]				Site occurrences[1]				% of Productive sites[2]			
	Tot. Rivs.	Tot. Crks.	T. Res. & Lks.	Tot.	Riv.	Res. & Crks.	Lks.	Tot.	Riv.	Res. &. Crks.	Lks.	Tot.	Riv.	Res. & Crks.	Lks.	Tot.
1.	0	1	0	1	0	3	0	1	0	2	1	3	0	4	6	3
2.	12	22	10	44	23	73	77	46	7	28	14	49	37	54	82	56
3.	17	6	0	23	32	20	0	24	2	3	1	6	11	6	6	7
4.	6	6	0	12	11	20	0	13	0	0	0	0	0	0	0	0
5.	11	10	0	21	21	33	0	22	0	6	2	8	0	12	12	9
6.	4	0	0	4	8	0	0	4	0	0	0	0	0	0	0	0
7.	35	17	5	57	66	57	38	59	1	13	2	16	5	25	12	18
8.	21	1	0	22	40	3	0	23	0	0	0	0	0	0	0	0
9.	1	6	0	7	2	20	0	7	0	0	0	0	0	0	0	0
10.	1	9	0	10	2	30	0	10	0	0	0	0	0	0	0	0
11.	10	14	1	25	19	47	8	26	5	21	5	31	26	40	29	35
12.	6	0	0	6	11	0	0	6	3	1	0	4	16	2	0	5
13.	2	0	0	2	4	0	0	2	0	0	0	0	0	0	0	0
14.	27	8	2	37	51	27	15	39	9	4	0	13	47	8	0	15
15.	37	5	6	48	70	17	46	50	13	7	4	24	68	13	24	27
16.	3	0	2	5	6	0	15	5	0	1	0	1	0	2	0	1
17.	3	7	0	10	6	23	0	10	2	0	1	3	11	0	6	3
18.	9	3	0	12	17	10	0	13	2	3	0	5	11	6	0	6
19.	0	1	0	1	0	3	0	1	0	0	0	0	0	0	0	0
20.	0	2	0	2	0	7	0	2	0	1	0	1	0	2	0	1
21.	1	2	0	3	2	7	0	3	0	1	1	2	0	2	6	2
22.	0	0	3	3	0	0	23	3	1	0	1	2	5	0	6	2
23.									3	3	0	6	16	6	0	7
T.	**206**	**120**	**29**	**355**					**48**	**94**	**32**	**174**				
Sites																
A.	53	30	13	96					19	52	17	88				
B.	20	6	1	27					19	37	2	58				
T.	**73**	**36**	**14**	**123**					**38**	**89**	**19**	**146**				

[1]The number of collection sites at which a taxon was collected.
[2]Site occurences divided by productive sites.

Unionid biodiversity in the Smoky Hill system was originally concentrated in the lower portions of system rivers and in the eastern-most creeks. Within the Republican Basin, most unionids have probably always been located in creek habitat due to the shifting sand substrates of the rivers.

Bivalve habitat in the region has been severely damaged as a result of declining water flows due to surface and subsurface water withdrawal, as well as to unrestricted grazing and possibly to the impact of various pollutants. Protection of surviving habitat is important if the remaining unionid genetic diversity of the region is to be preserved.

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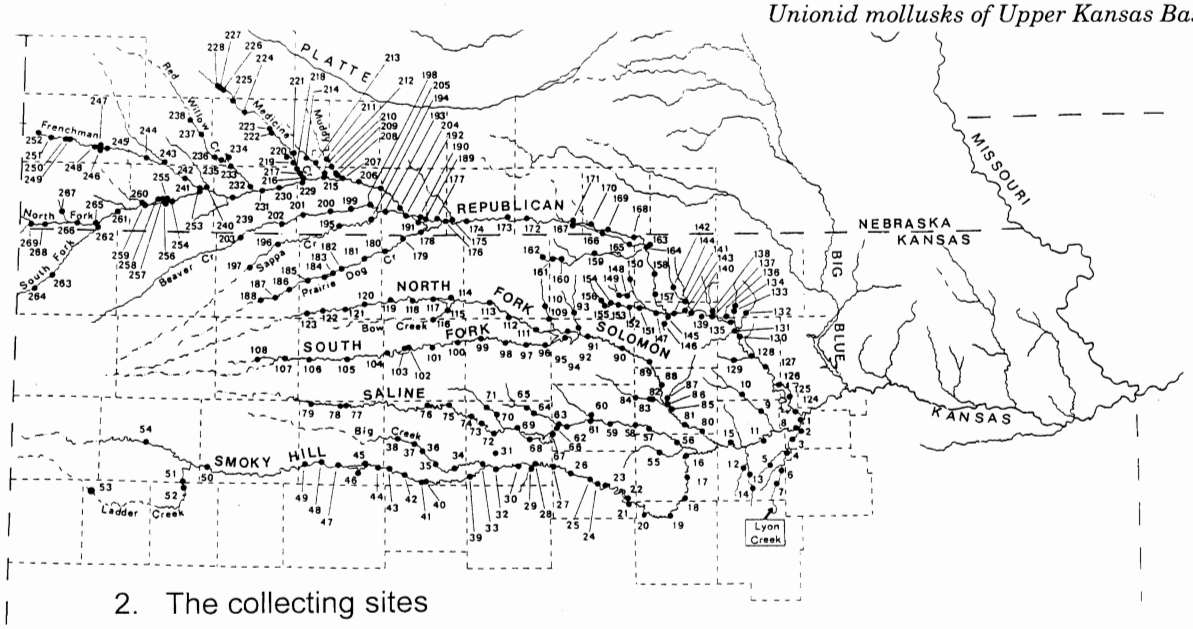
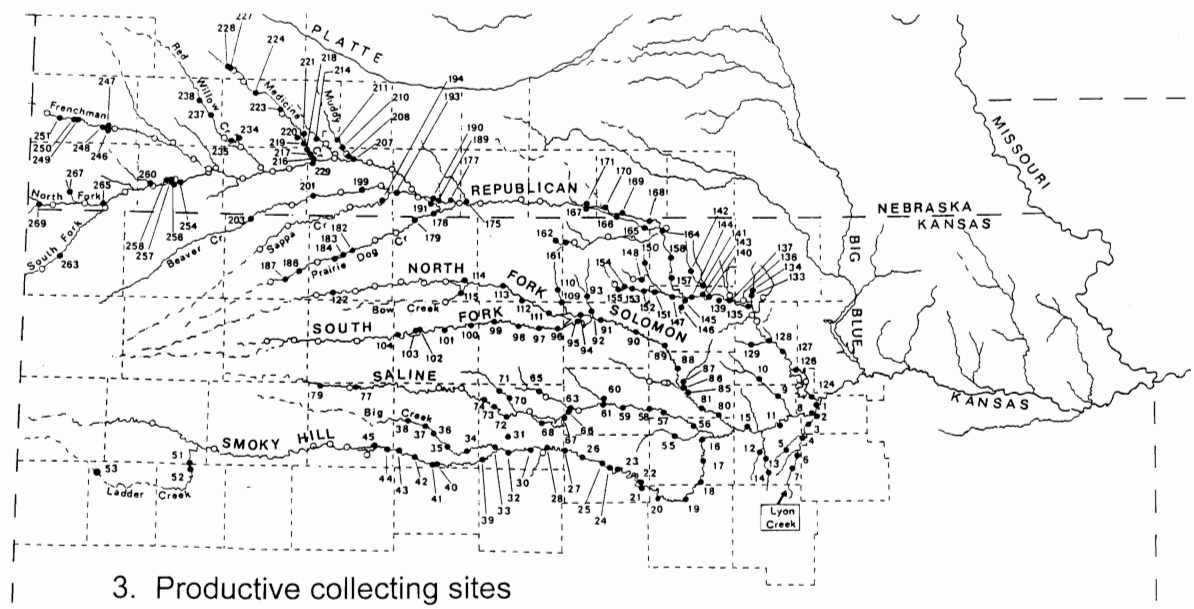
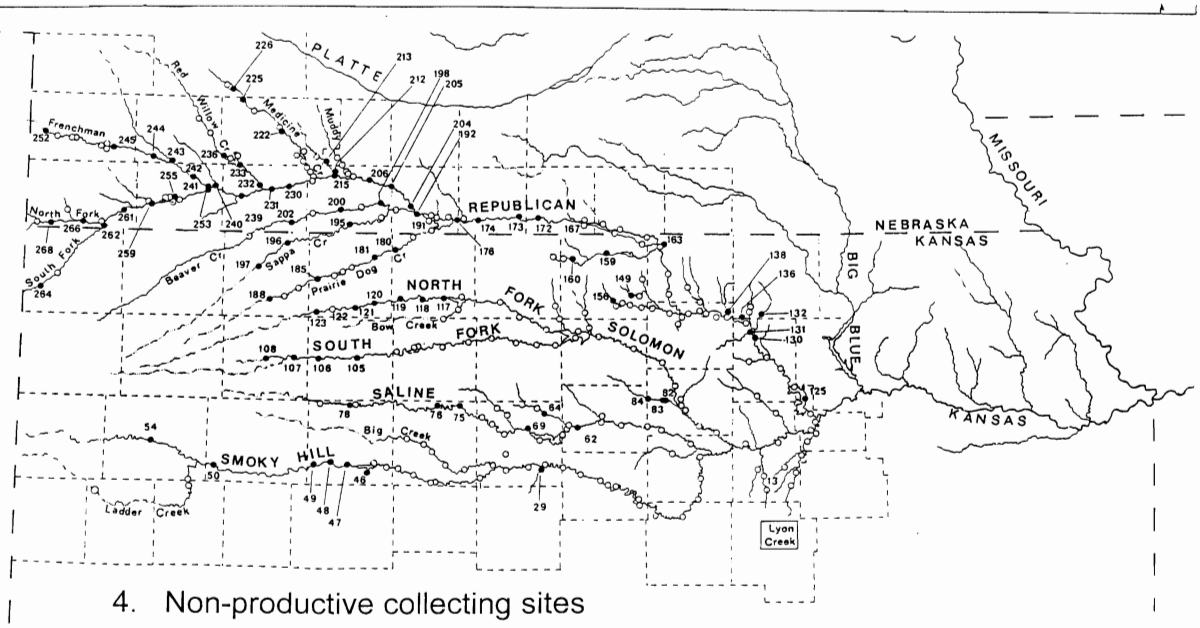


2. The collecting sites



3. Productive collecting sites



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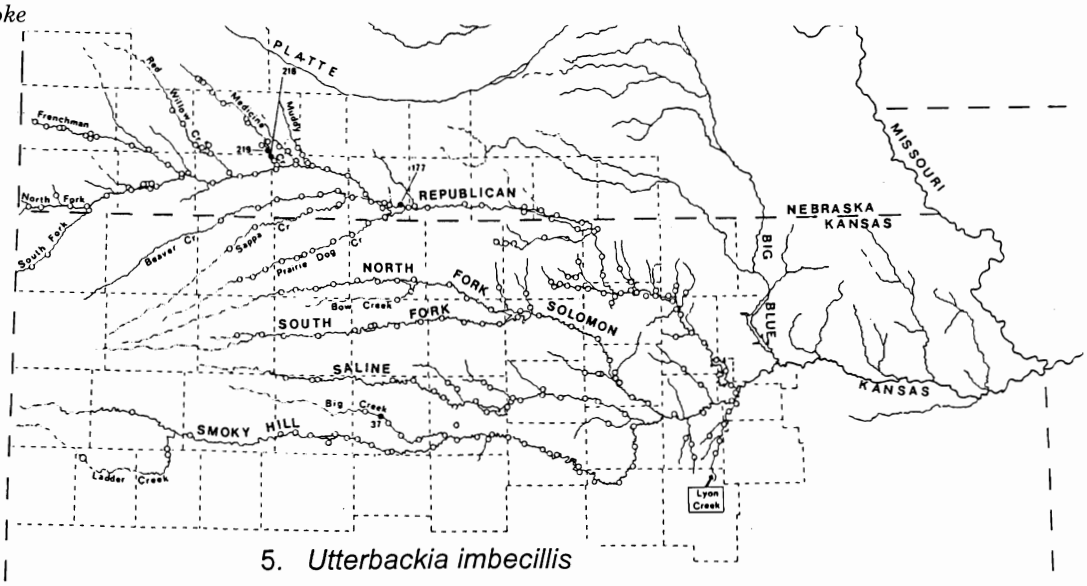
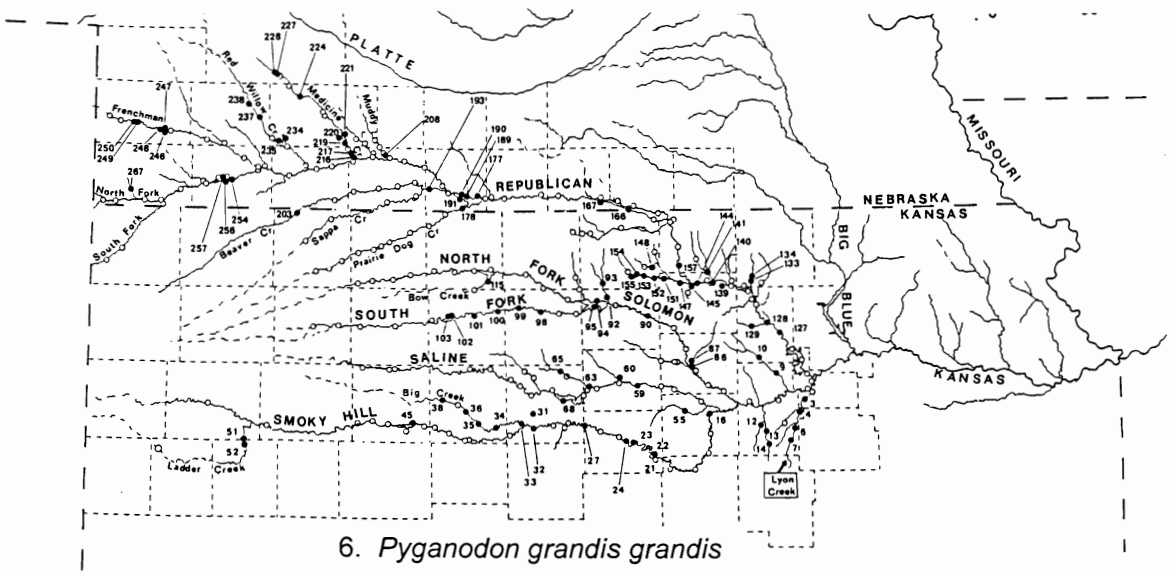
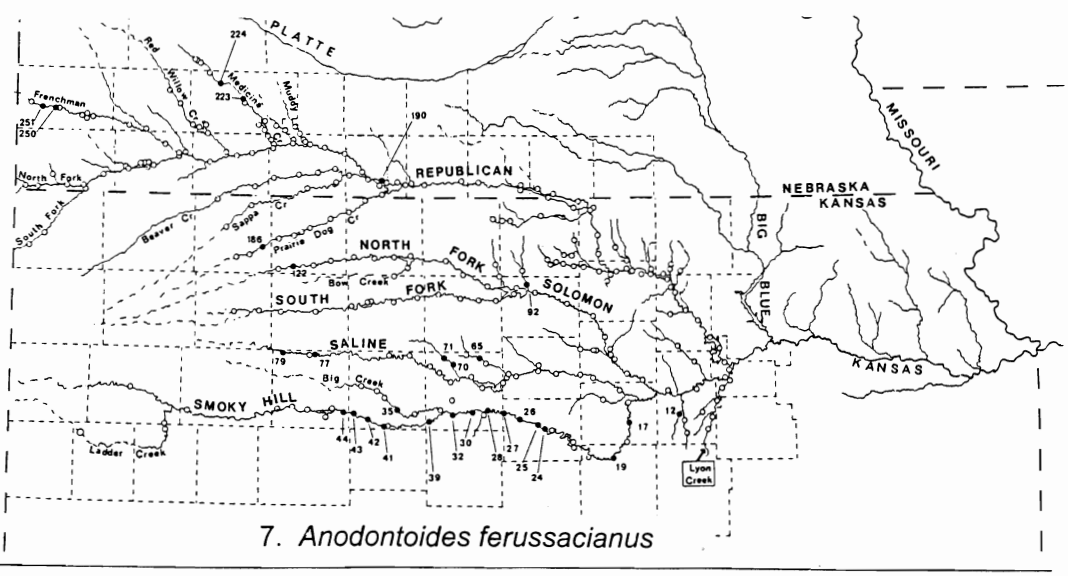


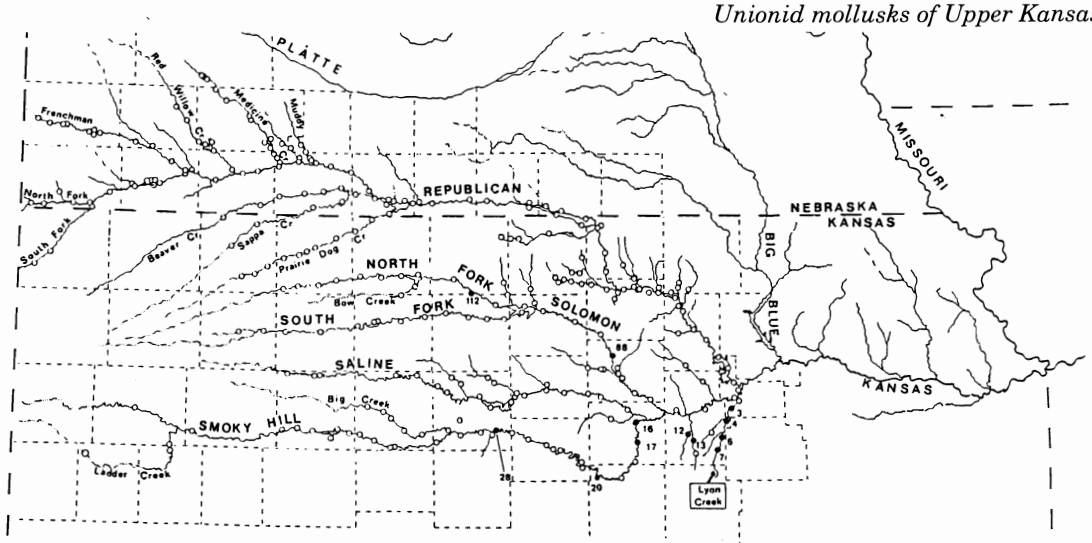
5. *Utterbackia imbecillis*



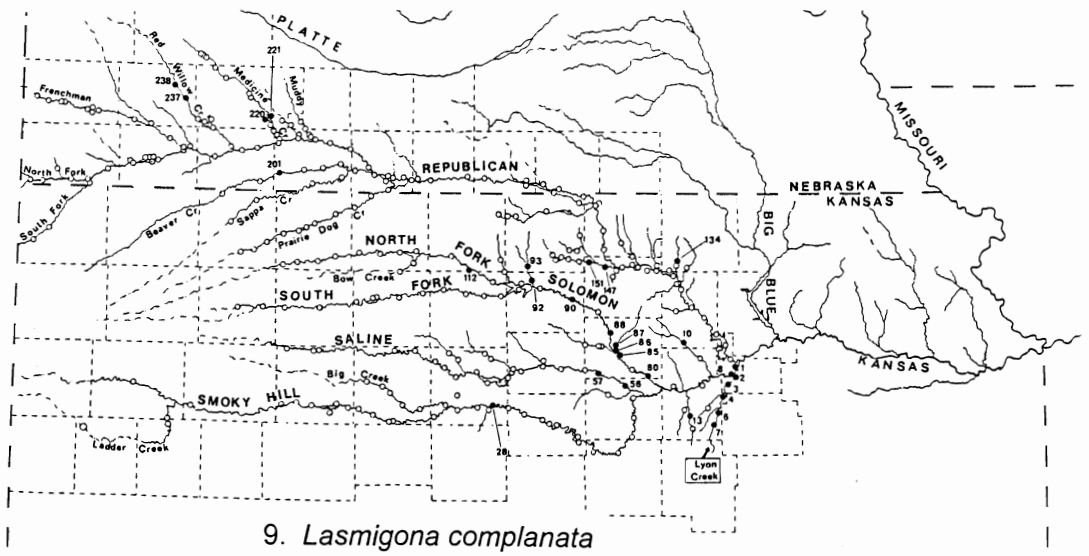
6. *Pyganodon grandis grandis*



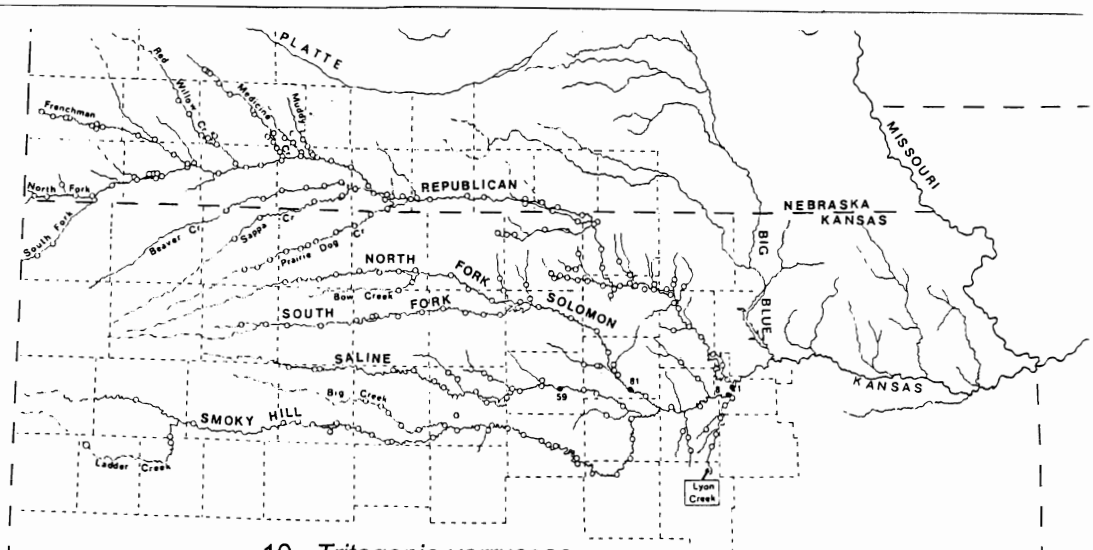
7. *Anodontoides ferussacianus*



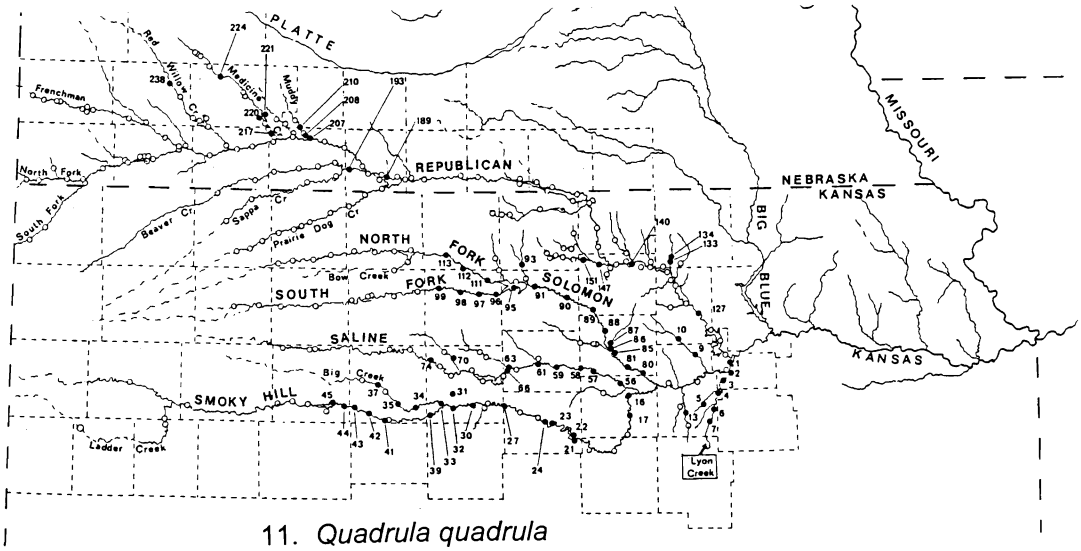
8. *Strophitus undulatus undulatus*



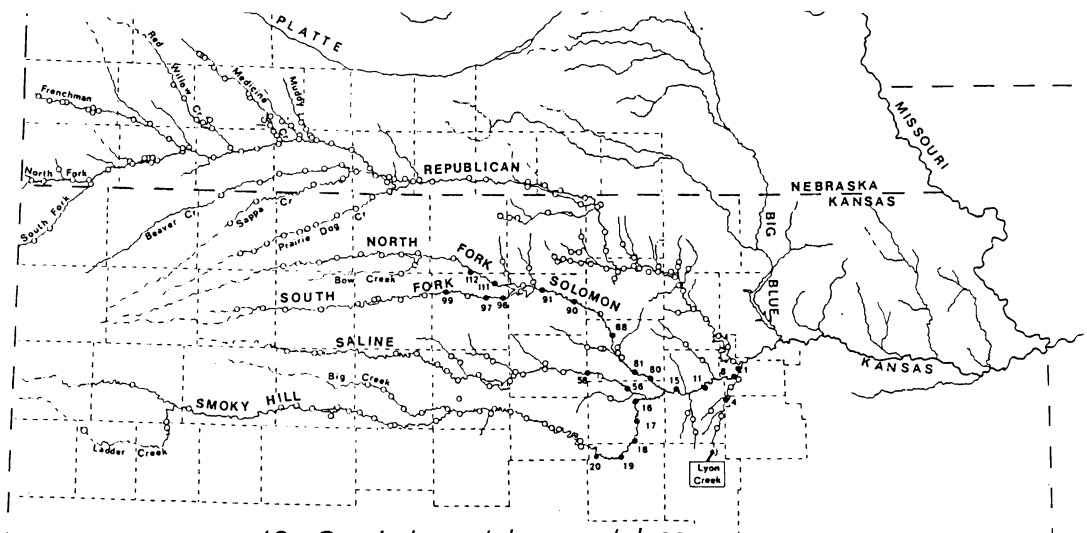
9. *Lasmigona complanata*



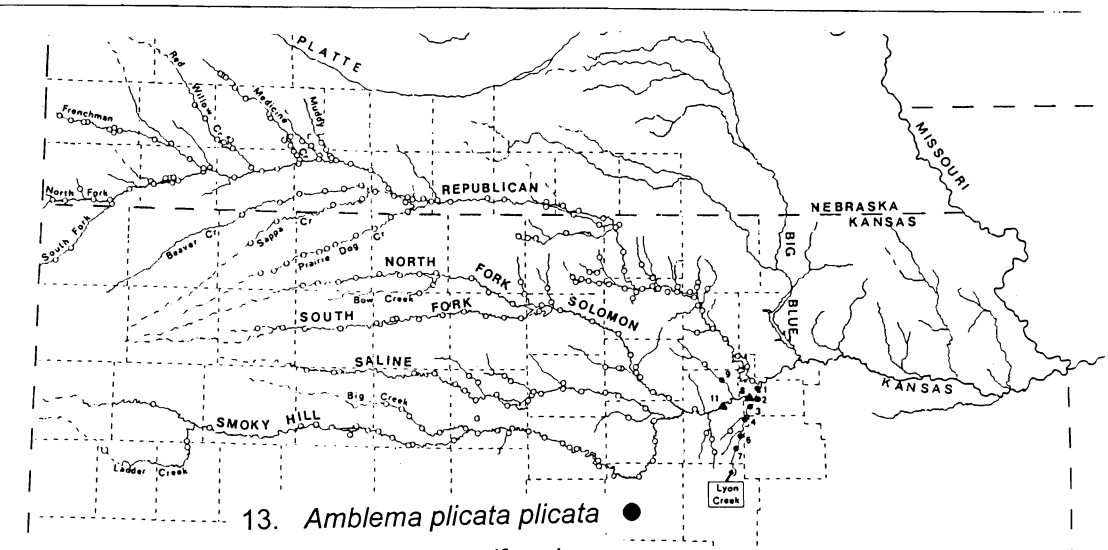
10. *Tritogonia verrucosa*



11. *Quadrula quadrula*

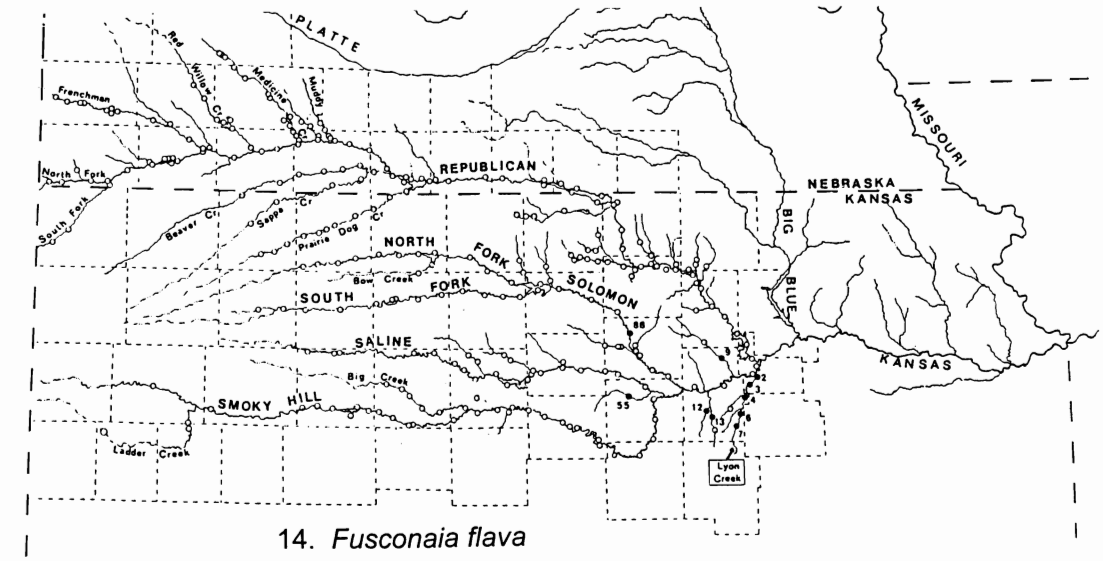


12. *Quadrula pustulosa pustulosa*

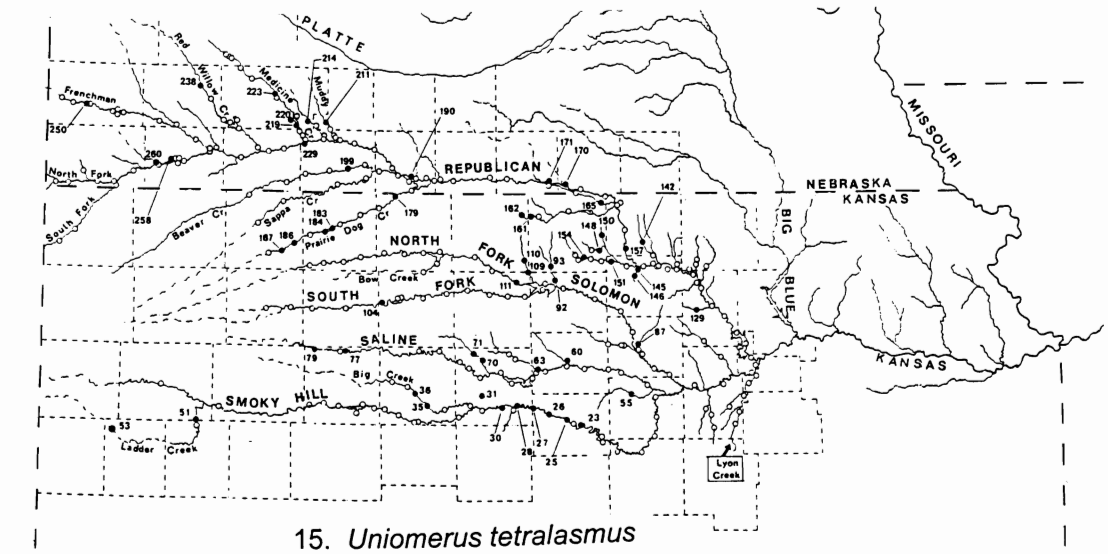


13. *Amblema plicata plicata* ●

Truncilla donaciformis ▲



14. *Fusconaia flava*



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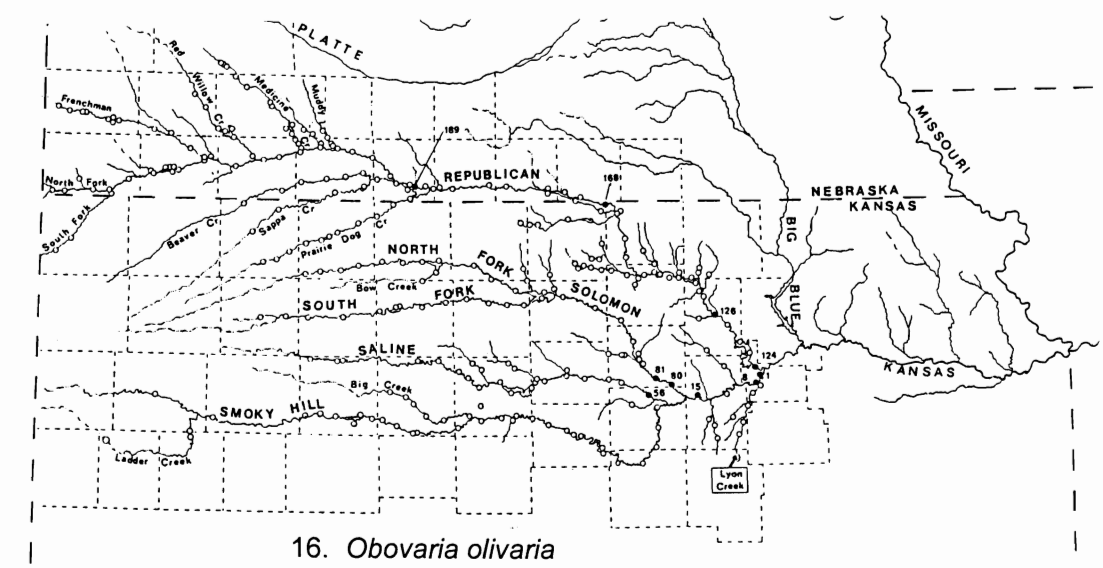

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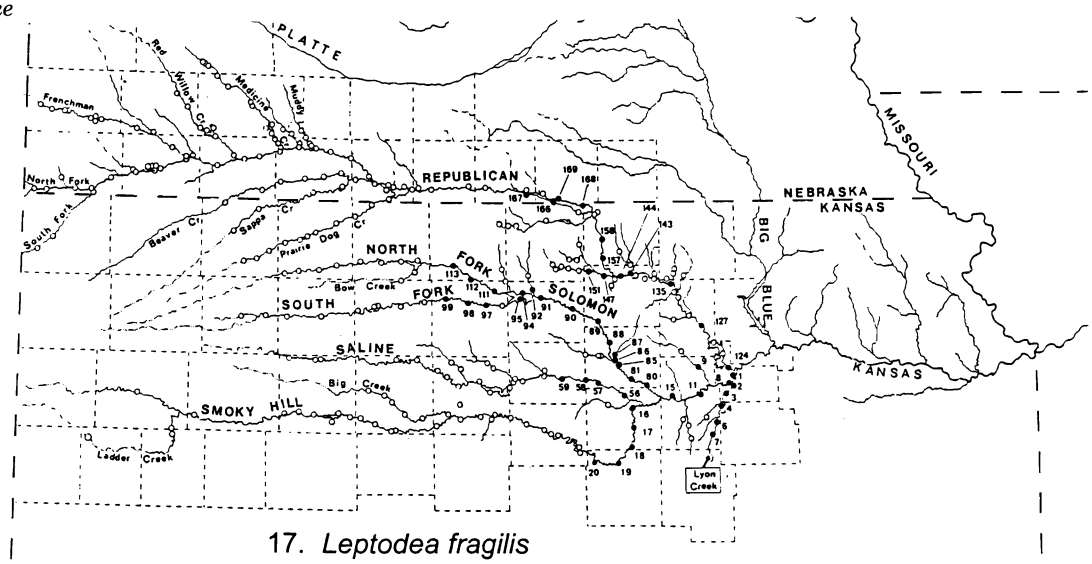

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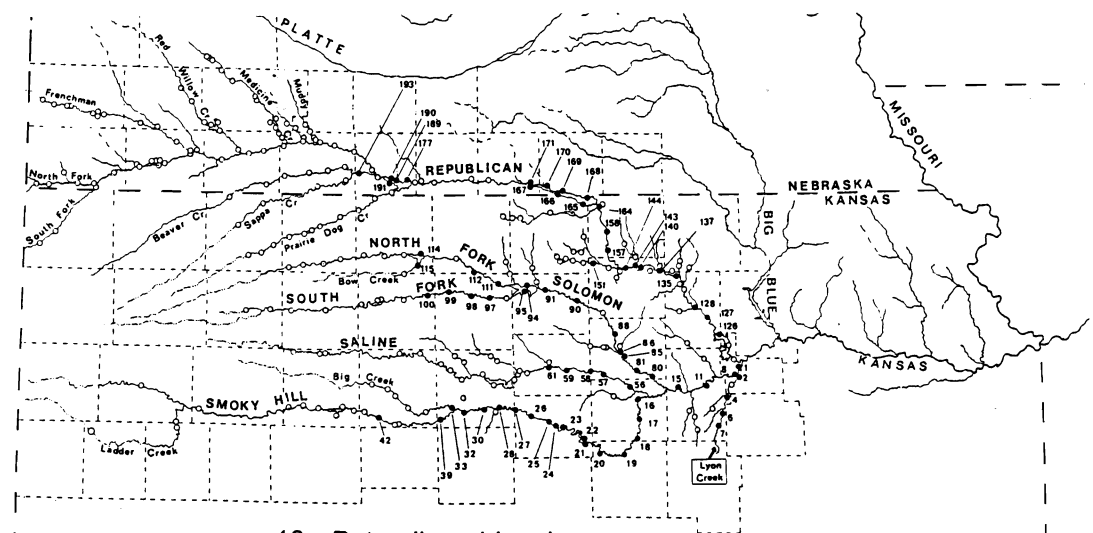

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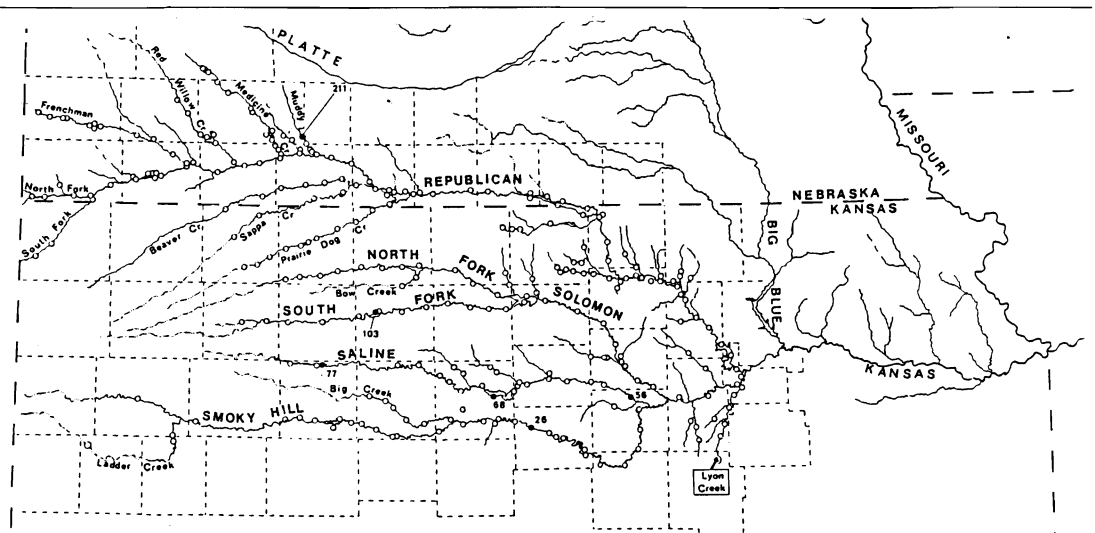

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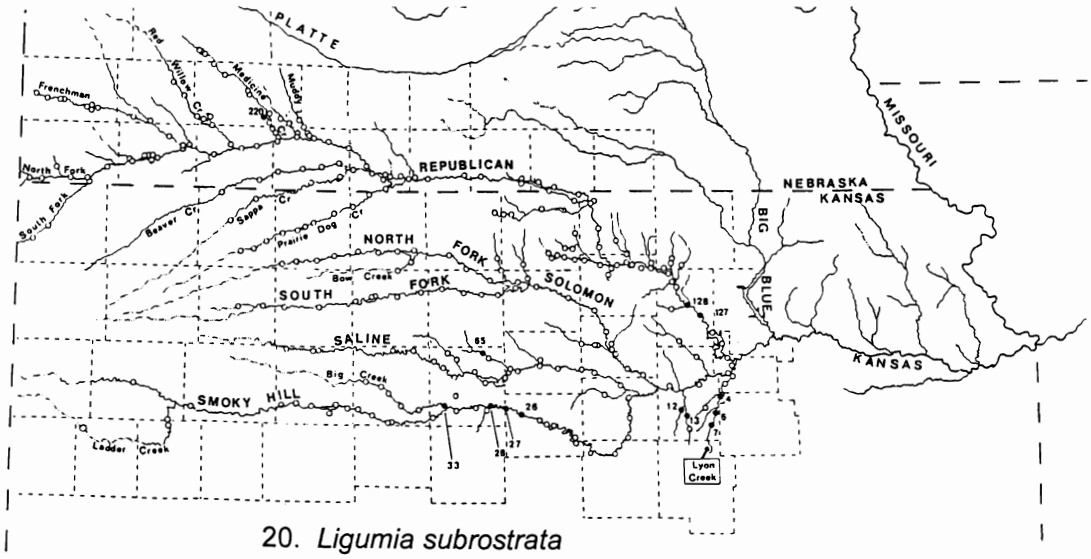
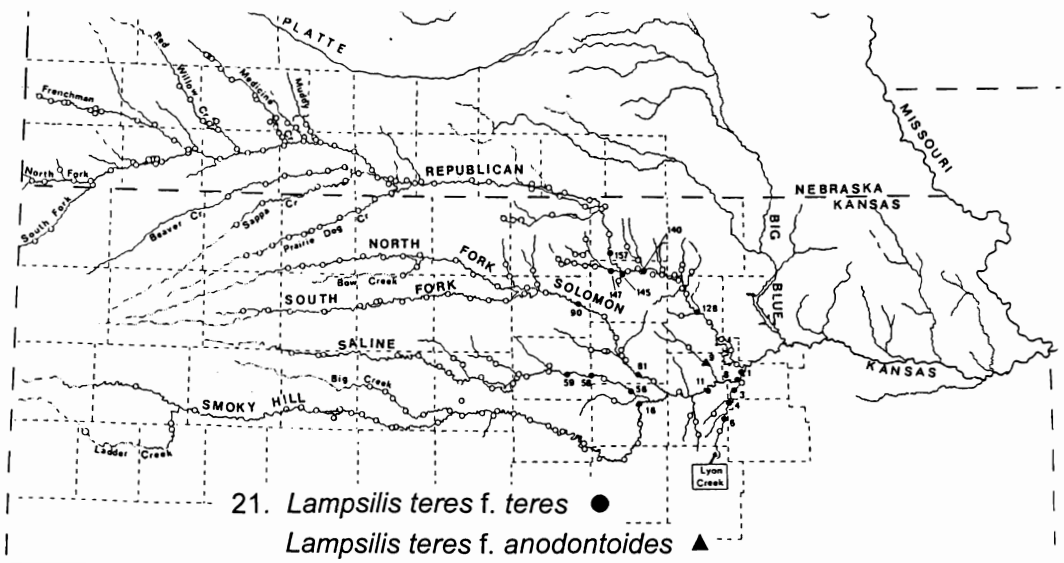
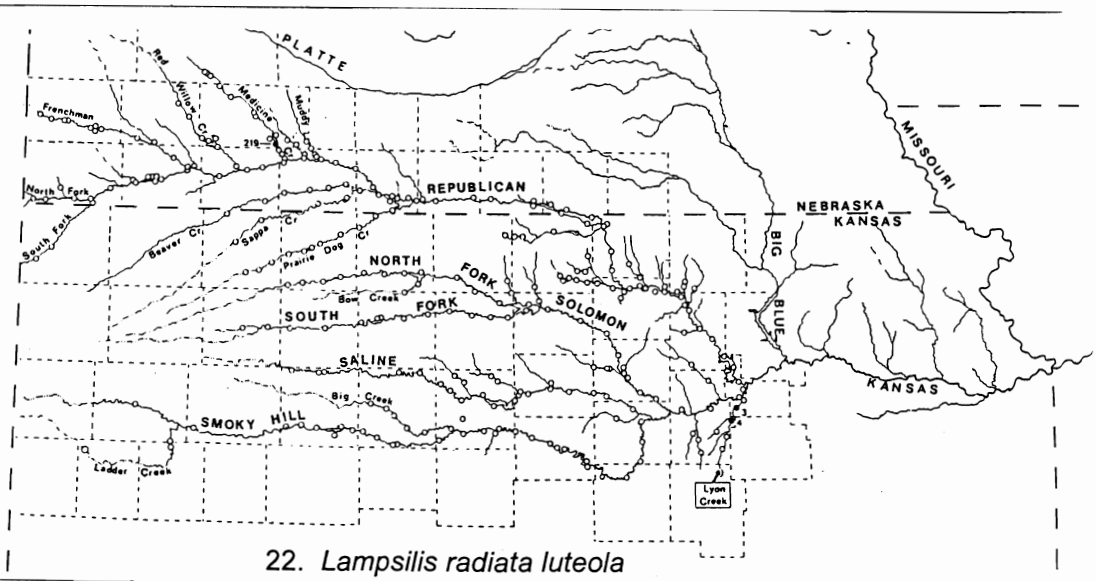


20. *Ligumia subrostrata*



21. *Lampsilis teres* f. *teres* ●
Lampsilis teres f. *anodontoides* ▲



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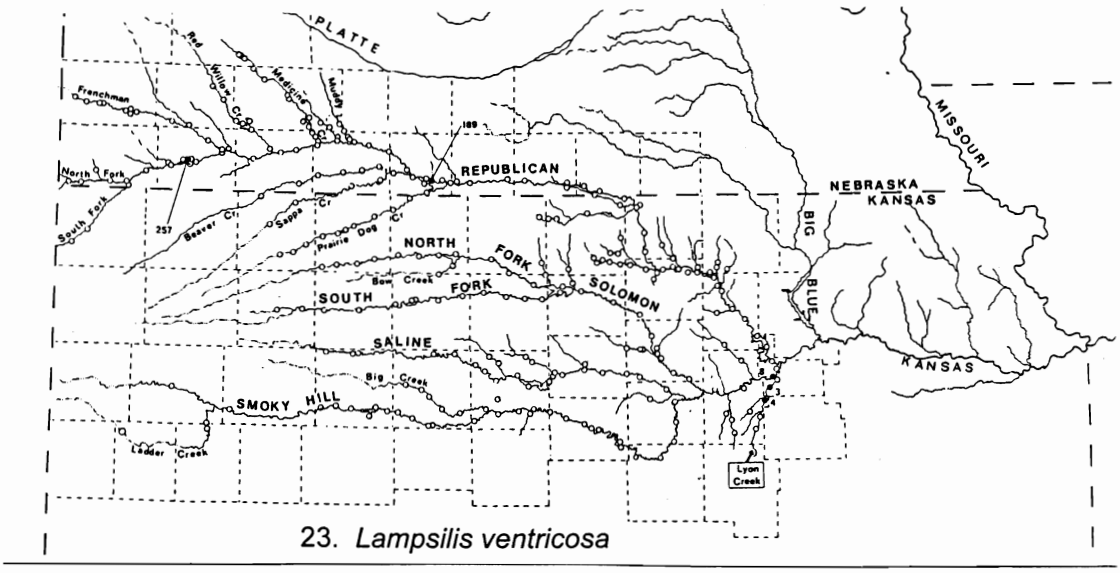

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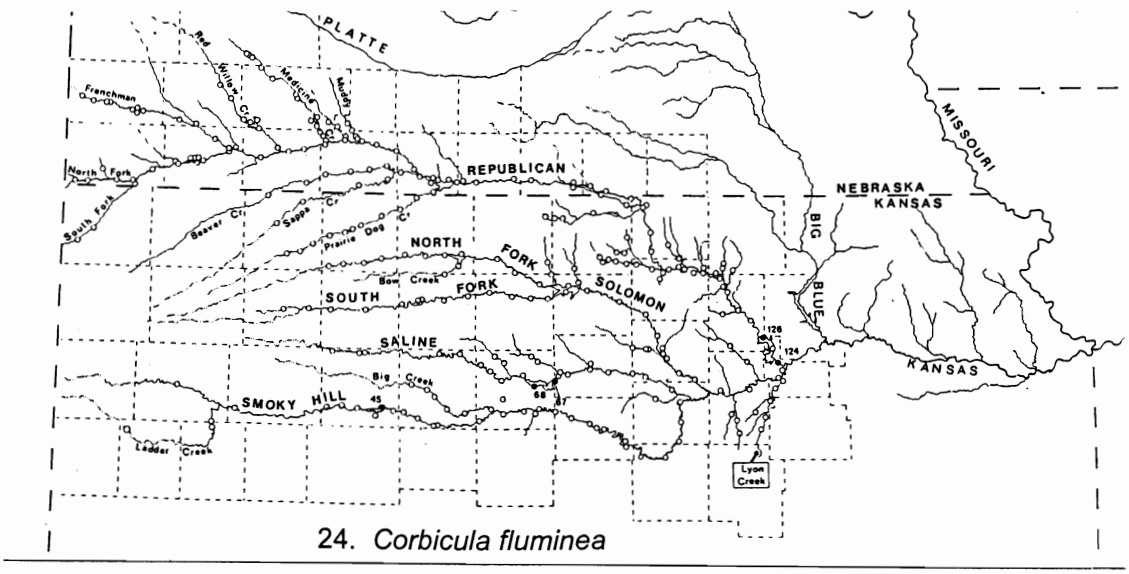

24. *Corbicula fluminea*